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RADIO INTERFERENCE FROM HIGH VOLTAGE SYSTEMS.

BY

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In the present communication, an account is given of recent investigations carried out and the remedies proposed for eliminating disturbances from high voltage transmission systems. In the past decade, the radio broadcast listener has been the most affected by interferences; but the broadcasting companies, electrical manufacturers and public utilities are likewise concerned, since the solution of eliminating the interferences falls upon them. During the past three years, considerable improvement has been made to eliminate unnecessary interference; and recently every kind of equipment used in the supply and consumption of electrical energy was tried and tested for interfering qualities.

According to past experience, radio interference may be classified under the following headings with respect to its origin. These sources are: (1) Consumer's equipment and apparatus; (2) Low voltage circuits and commercial apparatus; (3) Intermediate voltage circuits and general equipment; (4) High voltage equipment, etc.; (5) Atmospheric disturbances under all weather conditions.

Numerous methods and devices have been devised for eliminating all possible radio interference originating on any

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of the first three classes of equipment. The fourth item includes various equipment which can be made free from radio interference, and especially those concerning pin and suspension type insulators, which come within the scope of this paper. The fifth classification is a rather peculiar phenomenon, but nevertheless it has been studied in various ways with promising possibilities for the future.

General Conditions.—The principles underlying radio interference are similar to those of wireless telegraphy and commercial carrier current telephony. It is known that a spark occurring on any type of electrical equipment sets up a wave train which produces damped oscillations of different frequencies. The predominating frequencies are the resonant frequencies of the associated networks and their harmonics, including those in the radio broadcasting band. Since the electrical constants which determine these frequencies are uniformly distributed, the resonant peaks are generally broad and overlapping. Therefore, a broadcast-receiver possessing radio interference is frequently affected over the entire broadcasting range. The ultra sensitiveness of modern broadcast receivers, and the energy used from a.-c. lines, make them highly susceptible to radio interference. Consequently, the comparatively small amounts of energy involved in the electrical discharges are sufficient to produce an intensive disturbance in the broadcast receivers, especially when the discharges occur along high voltage lines as found in practice.

The distinction between corona and brush discharge should be borne in mind when radio interference from line insulators is considered. A corona discharge usually occurs at lower voltages than a brush discharge and appears as a bluish glow. A brush discharge occurs after the corona and appears in the form of white streamers. It is usually considered as another form of corona discharge because of the distinct interfering characteristics of the two discharges. In a broadcast receiver, every corona discharge produces a soft hissing sound, while a brush discharge emits a crackling, sharp high pitch noise which is very annoying.

Pin Type Insulators.—In order to prevent radio interference on any power line, all discharges must be arrested. To accomplish this purpose, all hardware must be made taut and any adjacent pieces must be sufficiently separated, or bonded together. All conductors and tie-wires must make perfect electrical contact with the top face of the insulators, and the pins should also make perfect electrical contact with the surface of the thread in the pin holes. On power lines using pin type insulators, these requirements can be fulfilled with the exception of the latter two. Where conductors, tie-wires and pins do not make perfect electrical contact with the surfaces of the insulators, every insulator becomes a potential source of radio interference immediately.

For a better conception of the present discussion, let us assume a standard pin type insulator as the dielectric of a condenser with the conductor and tie-wire acting as one plate and the pin acting as the other plate. Now, when a potential is applied to both plates, a charging current, the magnitude of which is determined by the reactance of the condenser and the applied voltage, immediately will flow into the condenser. Moreover, since the reactance of the condenser is a function of its electrostatic capacity and the frequency of the applied voltage, it is reasonable to understand that the charging current is affected by the three important factors, voltage, frequency and capacity.

Let us now consider, for example, a 66 KV. pin-type insulator of which the electrostatic capacity is about 10 $\mu\mu$f. We will have a charging current of 0.14 milliampere flowing into it when used on a 60 cycle 38 KV. power line to ground. Eventually, if the conductor, tie-wire and pin, all made good electrical contact with the insulating surfaces, the charging current could easily flow into the insulator. As usually found in commercial practice, resistance is offered to the flow of charging current by poor contact between the conductors, pins and insulating surfaces. Since the dielectric strength of air is lower than that of the insulator material, the differences of potential at these points of imperfect contact are sufficient to ionize the immediate surrounding air, with the ensuing result of producing corona and brush discharges. From the preceding discussion, it is a comprehensible fact that radio interference from pin type insulators can easily be reduced by overcoming resistance to the flow of charging current into the line insulators.

As mentioned before, the magnitude of the charging current flowing into the insulator is determined by the applied voltage and frequency, and by the electrostatic capacity of the insulator. It is therefore evident, according to recent experiments, that a reduction in these factors will decrease the charging current. In modern operated systems, the voltage and frequency are fixed, but the capacity can be reduced by excessively insulating the power lines and yet remain within reasonable expense from the engineering standpoint. This method has met with interesting success on certain transmission lines operating up to 88 KV. However, in addition to overinsulation the best solution is to insure perfect contact between the conductors, tie-wires and insulator surfaces. On the present existing pin type insulators in service, satisfactory results can be obtained by treating the insulators and pinholes with a compound known as Zapon after proper contact is made between the wires, pins and insulators.

Another method that is feasible is by looping the tie-wire to form a ring several inches in diameter over the head of the line insulator. A layer of metal gauze placed in the tie-wire groove has proved very effective, when used with the ring and the Zapon compound, which is not affected by weather conditions and inexpensive to apply. The metal gauze enables a reduction in current density where the conductors and tie-wires make contact with the insulators. Where the insulators were treated with the transparent Zapon compound over three years ago, very satisfactory results have been obtained and especially when subjected to rated voltage in comparative tests. Some manufacturers employ a metal cap on the insulator head, or very thin layers of metal to the heads and wire grooves, but these methods do not stand up under practical conditions for any considerable length of time.

Apparently, the use of metal caps and metal coatings on the heads of pin type insulators will lead to an increase in the electrostatic capacity of such insulators. Furthermore, the charging current will be increased and likewise, the current density at the surface of the pin-hole will be increased. It is therefore advisable that the pin should make the proper contact with the insulator. In some cases where the insulator was found to be defective after several years of service, the pin-hole was treated with a mixture of Zapon and fine copper filings, and the ring-loop and gauze attached as aforementioned. The results have been very good after three years of service on a 66 KV. transmission line.

Suspension Type Insulators.—There are three classifications of suspension insulators, namely, cap-and-pin, link, and spider type. In past experience, the suspension insulators as a group have been considered to be free from radio interference. In practise the potential impressed upon each disk of a string is comparatively low. On 55 KV. transmission lines using three units per phase, the maximum voltage is about 11,000 volts. On 110 KV. lines using from six to seven units per string, the maximum duty per unit is 14,000 volts. For 220 KV. lines using fourteen units per string, the maximum potential per unit is 23,000 volts without shields or grading rings, and about 15,000 volts with such devices. When single ball-and-socket type suspension insulators are tested in the laboratory, a corona appears at the cap, and at the pin when potentials of 18,000 volts are applied. When potentials of 25,000 or 26,000 volts are applied, a brush discharge usually occurs. It is therefore seen that this type of suspension insulator should be free from causing radio interference under ordinary conditions.

It has been observed that corona and brush discharges appear on clevis type insulators at similar potentials, when the cotter key is removed from the clevis bolt. With the cotter key in place and the pointed ends turned upward, brush discharges usually occur between the points of the key and the innermost petticoat at voltages as low as about 11,000. Even the cotter keys on clevis type insulators which have been in service on 110 and 132 KV. circuits for a period of four months show clear evidence of a feeble brush discharge at both the pointed and round ends. The cotter keys on the units next to the line show greater signs of brush discharge than the cotter keys on other units. From these indications, it is apparent that the cotter key is at fault on the clevis type insulator and the method of eliminating this source of interference will be explained hereinafter.

Link type insulators are even more apt to cause interference than the clevis type. In the older models, brush discharges occur at potentials of 1,900 volts per unit. In the modern link type insulators, they employ soft copper links and lead shims so as to obtain better contact between the metal and the porcelain. However, without loading, radio interference begins at 6,000 volts per unit, while under a 350 pound tension, interference only starts when 14,100 volts are impressed. While it is known that the potential across the line unit of a string of six link type insulators as used on a 110 KV. transmission line is about 20,000 volts, interference will occur under those conditions.

On the spider type of suspension insulator, corona discharge begins at a potential of 21,000 volts when applied across individual disks, whereas a brush discharge occurs at 25,500 volts. It is seen that both discharge points are higher than the corresponding points for either link type, or cap-and-pin insulators. This important fact is accounted for by the large porcelain used in this type of insulator and the absence of sharp points or unfinished edges at points of high electrostatic flux density. Both the ball-and-socket type and the spider type insulator are designed for certain values of mechanical strength, flashover voltage and leakage distance more readily than for high values of corona or brush discharge voltage. Since the discharge points are higher than the customary operating voltages, these insulators have been found satisfactory from the point of view of radio interference.

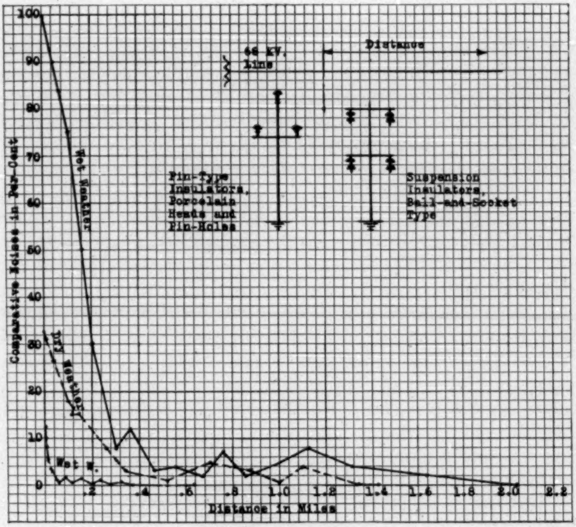
The clevis type insulator is also satisfactory, especially when the cotter key is properly designed. Recently, one large manufacturer has designed a clevis type insulator in which the cap is recessed to overlap the cotter key and prevent it from turning. A method which was tried and found advantageous in this insulator is that of replacing the regular cotter key with a circular key, so that the ends are concealed inside the clevis bolt when in place. Recent results obtained from comparative tests have indicated that the clevis type insulators equipped with circular cotter keys are on an equal basis of giving satisfaction as the ball-and-socket insulators.

A number of high tension transmission lines now employing suspension insulators, also use arcing horns to protect the conductors and insulator disks during flashover. Grading rings and shields also fulfil this purpose and change the voltage distribution along the insulator string, and so enable a reduction in the maximum potential per unit. Various tests show that the arcing horn is the only one of the above mentioned devices causing radio interference. When brush discharges occur at the horn-ends, they produce an interference similar in sound to that of pin insulators. Fortunately, brush discharges can be eliminated in the present type of arcing horn by placing a small metal ball on the end of the horn. The recompense, nevertheless, is an increase in the surface area and sharp points are thus avoided.

Interference from Other Sources.—Experience has proven a great similarity in the behavior of pin type and suspension insulators when they collect dirt and moisture. The presence of either increases the amount of interference, especially on pin type insulators. Rigid tests carried out by electrical engineers and physicists recently show a high percentage in disturbance caused by insulators when wet or dirty. Defective insulators mostly set up peculiar disturbances which seriously affect radio receiving apparatus for many miles. Any cracks or projections on the surface of the insulator, or where the tie-wires are not properly secured to the conductor, frequently cause serious interference. The usual remedy for such cases is replacement of defective insulators, cleaning of dirty insulators and then applying a coat of Zapon glaze to the surfaces. The Zapon can be used freely over the insulators or any joints and connections, where it dries quickly and at the same time acts as a very reliable preservative. It is also essential to properly inspect and maintain all high voltage lines in order to eliminate radio interference under all weather conditions.

Attenuation of Radio Interference.—To attain an idea of the distances to which interference will travel before it is reduced to a non-interference level and disclose the effect of excessive insulation, the curves plotted in Fig. 1 show the result of attenuation of radio interference when propagated along a transmission line. The experimental investigations were carried out on different high voltage systems in which each section is constructed with pin-type and ball-type suspension insulators. The resultant effects of interference seem to correspond in value for transmission lines operating at potentials from 33 KV. to 88 KV. However, the origin of the curves is taken at a location where the two types of construction are connected together, and the abscissas are measured from that point along the section employing suspension insulators. The ordinates are measured by a milliammeter coupled to the output circuit of a modern superheterodyne receiver through a transformer. The readings of this meter

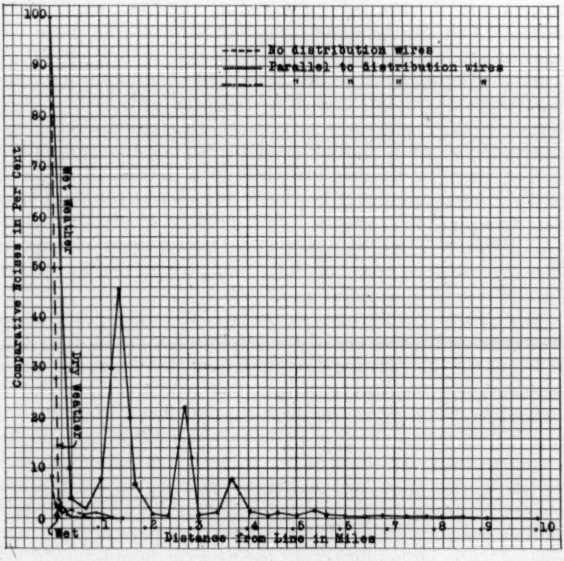
FIG. 1.



have no absolute value, but their significance becomes evident when the signals from a large radio broadcasting station 90 miles away, as in this particular case, was heard with noise levels of 8 to 15 per cent. At 8 per cent. the signals were nearly equal in intensity to the interference noise, while at 5 per cent. the signals were apparently stronger than the interference. With a zero reading on the instrument, the interference was not serious, although the impulses could still be heard with the signals from the broadcasting station.

The readings for the full line curve were taken during wet weather and those for dry weather are indicated by the dotted curve. The short dot and dash curve shows the readings taken after interference was fairly minimized through the methods described. Moreover, the dot and dash curve represents the readings during wet weather after 97 per cent. of the existing insulators were remedied. In the latter case, a slight amount of interference could still be heard at a distance of 5 miles from the radio broadcasting station, due to the effect of rain drops on the suspension insulators.

FIG. 2.



In Fig. 2 the curves are nearly similar to those of Fig. 1. These curves show the effect of attenuation at right angles to the same transmission line discussed in the preceding two paragraphs. There are two conditions which were observed and are important, namely, (*a*) no distribution lines to emit disturbance, and (*b*) distribution circuits paralleling the 66 KV. transmission line and joined to other circuits at right angles to the high voltage line. This condition of circuit installation may be found in all cities and small towns, and has become quite a problem to the radio engineer when dealing with interference. The best method of minimizing this kind of radio interference is by eliminating the effect at its initial source. This can be done if engineers follow the usual dictates of good practise as in choosing correct line insulators, bearing in mind always the local operating conditions, the importance of the line and other essential principles. Interference usually travels a considerable distance over transmission lines and is communicated from one line to another, so that remedial measures applied to a portion of a line or even reconstruction of a line may not always result in complete freedom of its effects. It is only by gradually tracing down all sources and by applying corrective measures thereto that expectations may be fully realized in making a line absolutely free from radio interference.

One power company has somewhat succeeded in remedying the situation by the use of radio-frequency choke coils connected in the distribution circuits, where they leave the transmission line. Another company has recently succeeded in preventing interference on high voltage lines from passing over its telephone circuits, by connecting choke coils to the telephone leads at those points where they leave the high tension lines. Standard lightning-arrester choke coils are unsuitable due to their low inductance. About a year ago, another company decided to use Smith carrier-current choke coils of high inductance and recent experimental evidence shows that very excellent results have thus far been obtained. Final details of their success will appear in a near future paper when a complete report is available. Other information with data will also be included on different types of insulators now in course of experiment on several transmission systems, and a new model which is being tried for certain advantages in the high voltage laboratory.

In conclusion, the author acknowledges his deep appreciation to Doctors P. Richard, R. A. Schwartz and G. H. Paelian for their active interest and valuable suggestions, and to Messrs, M. E. Steinbach, General Engineer, and F. M. Smith, Associate Director of Research, for their loyal coöperation in carrying out numerous investigations for the Continental Research Laboratories and the Universal Research Corporation.

Raisin Oil.—(*Food Industries*, **6**, 444.) According to ALBERT M. PAUL at least two thousand tons of cured grapeseed are collected annually in the course of preparing seedless raisins. These seeds when removed have a portion of the pulp still clinging to them. This pulp is worth recovering for it is approximately 80 per cent. dextrose. The seeds and pulp are first subjected to a sequence of washings with clear, warm water which dissolves the dextrose, giving a 12 to 14 per cent. solution. This dissolved grape sugar is transformed through fermentation and distillation into 191-proof brandy syrup.

The dried seeds normally contain about 15 per cent. of oil. This is expressed by a sequence of grinding, cooking and hydraulic pressing operations. The resultant cake from the presses finds use in stock seed, fuel and fertilizer. One of the most interesting uses of the oil is its return to the point of origin. There, it is sprayed onto the finished raisins, covering them all over with a thin film of raisin oil. This treatment adds greatly to the raisins' appearance by preventing them from clustering together in the package and better yet, they no longer stick to and cloud up the transparent walls of their container.

Raisin-seed oil finds favor as a salad oil; it blends perfectly with olive oil. It makes a mayonnaise of good stability and texture. Its high fire and flash tests suggest its use in the frying of doughnuts and potato chips, to which it imparts an attractive non-greasy flavor. Much of this oil has been used on canvas, for awnings and airplane wings wherein its relatively slow drying factor and its high spreading quality are of particular utility. Canvases are left soft and pliable, when oiled, instead of becoming harsh and stiff.

C.

SNAPSHOTS FROM CLOUDLAND.

BY

W. N. JENNINGS.

PHOTOGRAPHS BY THE AUTHOR.

Much wind has gone through the airplane propeller since I became interested in aviation, and the evolution of human flight in one man's short lifetime is truly amazing.

The Psalmist, to-day, would not yearn for "the wings of a dove," for now man flies around the globe swifter than a swallow, higher than an eagle, and to-morrow all the world will be a-wing seeking new aerial worlds to conquer; another Picard, sealed in a metal sphere, will rise above earth's atmosphere to solve the secret of the cosmic ray, and a future Goddard will try by rocket-power to sail over the mountains of the moon, navigate the Martian canals, flirt with Venus, or bring back close-up views of the "Milky Way."

Even at this moment a U. S. Naval Officer gravely petitions Congress to set aside one hundred thousand dollars in aid of planetary exploration; while appropriations for aircraft now run into the billions. To-day we no longer cynically smile at these air-brained dreamers, who now have no difficulty in finding capital to back their flights of fancy; and yet, it was only yesterday that poor Langley was literally laughed to death when his weird contraption, which he called an "Aerodrome," fell and floundered, with its pilot, in the waters of the Potomac; and that same aircraft, when later furnished with a modern gasoline motor, made several successful flights.

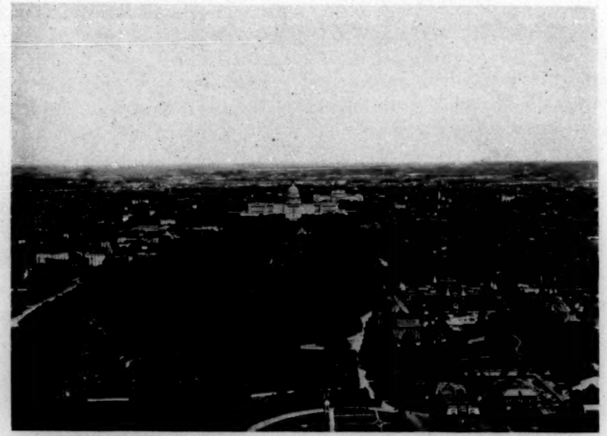
It seems only a short time ago to the present writer that he joined an early morning crowd in a field near Dover to greet a smiling figure that had hobbled out of a tiny monoplane, to learn that this was Bleriot, just arrived from Calais. over the English Channel, the intrepid Frenchman having been so anxious to beat his British rival, Latham, that he entirely overlooked misty weather and the fact that he was just recovering from a broken leg. Next day I saw brave Bleriot in London, being borne upon the shoulders of his British admirers, and later found myself jammed in a three-abreast, four-block deep crowd waiting outside the Selfridge Department Store on

The late Prof. Samuel A. King, The world's most famous aeronaut.

Oxford Street in order to gain another glimpse of that aero-midget that had brought its builder and flier fame and fortune.

And at this moment, above the tapping of my typewriter, comes a voice over the air announcing the safe arrival of two French fliers near Damascus, after a two-day non-stop flight from New York *in a Bleriot Monoplane*.

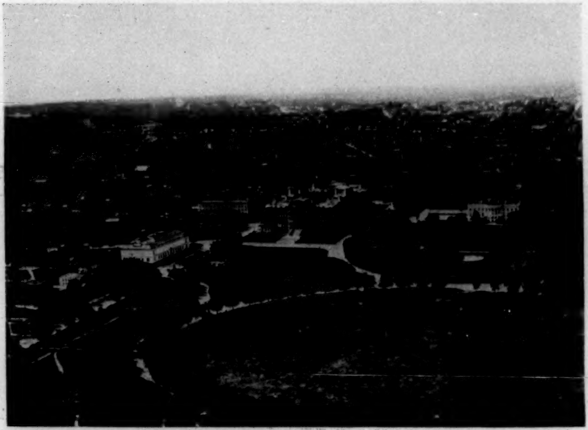
On the other hand, slow, indeed, has been the development of steam locomotion and navigation; there having been a long lapse of time between the "Rocket" of Stephenson and the "Royal Scotch Express," and a greater gap between Fulton's paddle wheeler, "Clermont," and England's latest Atlantic liner, "Queen Mary."



View from top of Washington monument on a misty day. Made with yellow filter and orthochromatic plate. (On an ordinary plate without color filter the capitol was not visible.) June 1892.

Slow, too, has been the progress of lighter-than-air craft since the Montgolfier Brothers furnished Pilâtre de Rosier a mammoth paper-lined hot-air balloon, in which that brave aerial pioneer, with his companion, marquis d'Arlandes, made the first man-flight in the presence of Louis XVI, the Queen, Royal family, and members of the Royal Academy of Sciences, among whom was our own Ben Franklin; the same Pilâtre de Rosier who afterward imprudently attempted to cross the Channel in a double balloon, one above the other; a hot-air balloon below and a hydrogen-filled one above; when sparks from a brazier of burning chopped straw put a sudden end to the flight and the life of pilot and helper.

Hydrogen supplanted hot-air, and later coal-gas gave the spherical balloon its buoyancy; but all attempts up to date to steer this pear-shaped craft and bring it down to a definite landing field, have proven failures. There have been no important improvements in the gas-filled spherical balloon, with the exception of the "drag-rope" by King, for over a hundred years.



Photograph made on a misty day from top of Washington monument using orthochromatic plate and yellow filter. June 1892.

Before the advent of the airplane came the "Hot-dog" of the sky, a non-rigid sausage-shaped balloon, in which Santos Dumont, a Brazilian, performed many crazy and extremely dangerous antics over Paris before he finally succeeded in steering the unwieldy craft around the Eiffel Tower and back to its starting place, thus winning a huge cash prize and world-wide publicity.

Afterward I watched young Beachy wabble around the Philadelphia City Hall Tower in a similar cotton-and-bamboo contrivance, with sliding weights to control upward and downward flight, which operation required the aviator to be an acrobat. Shortly thereafter, poor Beachy lost his life in doing aerial stunts over Hollywood.

Many years before I poked my camera over the rim of an airplane cockpit—in fact, while the schoolboy Wright Brothers were flying kites in Dayton—I watched "Professor" Samuel A. King, a former famous Philadelphia balloonist, inflating the "Eagle Eyrie" for a Fourth of July balloon ascension in Fairmount Park, and then and there developed a keen desire to go aloft and make snapshots from couldland.

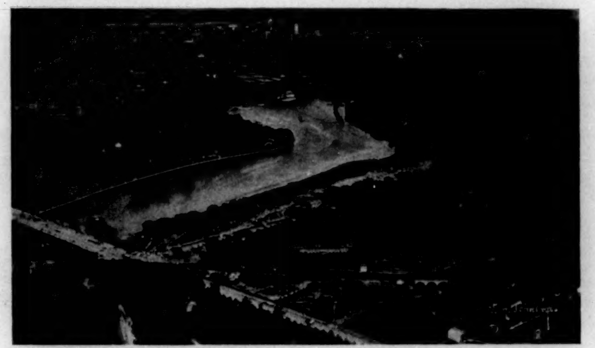
That ancient, heart-young, virile sixfooter personally attended to every detail of the inflation; carefully inspecting the netting; knotting and testing every rope connected with the suspension ring; shifting and straightening the balloon fabric; trying out the gas-valve, and coiling and attaching the six-hundred-foot drag-rope to the balloon basket, as the big gas-bag slowly changed from a mushroom to a mammoth golden gourd, "rarin'" to go aloft.

While resting for a moment from his many labors, I approached the genial aeronaut to make a bid for a place in the basket for the purpose of making aerial snapshots. The "Old Man of the Air" looked at me with an eye blue as the sky he loved to sail in; stroked his long beard, fleecy as any cloud he had passed through, and remarked:

"My charge for a passenger is fifty dollars; but if you expect to make good photographs on your first balloon trip I will tell you frankly that you will be wasting your time and money; for I have taken many photo-fiends aloft and have yet to see a skyscape worth printing." He then went on to explain that a budding balloonist on his initial flight is liable to do a lot of fool stunts fatal to good photography: Making two or more exposures on one plate; shaking the camera in nervous fingers; forgetting to withdraw the dark-slide or reset the shutter, using too large a lens stop, and greatly overtiming; also overlooking the fact that in summer-time he will find a blue haze between balloon and landscape, resulting in a thin, flat, washy negative; and in addition to all these troubles, there was danger of escaping coal-gas finding its way into the plate-holders and producing "chemical-fog."

By a process of elimination I decided to fight this aerial bugaboo to a finish, and soon thereafter made a series of experiments from the top of the Washington Monument. Holding my 6½ × 8½ camera in my hands, and pointing its 20″ lens at the capitol, faintly outlined in a slight mist, I made my first snapshot on an *ordinary* plate. The result was a thin, flat negative, with the capitol entirely missing.

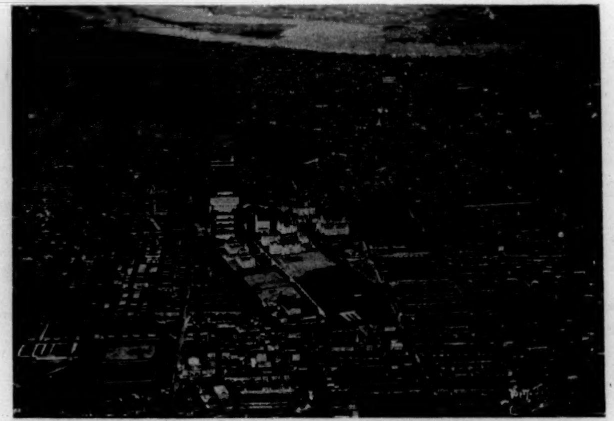
Next I repeated the experiment, using this time an *orthochromatic* plate, with a light yellow color filter over the lens, and was delighted to obtain a bright, snappy negative with the capitol clearly outlined. I duplicated this from each of the four windows at the top of the monument, with like results. In addition to this, for balloon work, I made my camera gastight.



First balloon photograph of Philadelphia, July 4, 1893. First time an orthochromatic plate and color filter were used for aerial photography.

When I showed these pictures to the "Professor" he was greatly interested. "Now," said he, "you will get good photographs from a balloon. Go to it." On the Fourth of July, 1893, when word was given to "let go" and the "Eagle Eyrie" balloon bore this cameraman, King and a fellow passenger aloft, the Municipal Band struck up "My Sweetheart's the Man in the Moon," and the immense crowd of up-lookers were squeezed together and evaporated; there being no sensation on our part of rising; the earth seemed to be sinking and slowly sliding beneath us. While I prepared the camera I heard King's voice coming from a long way off, which came close after I had followed his directions to swallow, when my hearing became normal.

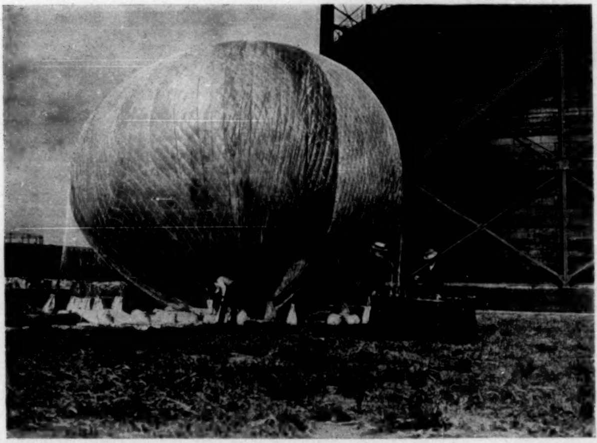
Balloon photography is quite simple. All I had to do was to forget nerves; rest the camera-bed on the edge of the basket, wait until the desired section of landscape came into view; hold my breath, and press the button. I made several exposures while passing over Philadelphia at the height of about a mile, *using orthochromatic plates and a color filter for the first time in aerial photography,* and securing sharp, crisp, clear-cut negatives, from which I afterward made a number of 40″ × 50″ enlargements for exhibition at the Crystal Palace, London. It is interesting to note at that time there were only two "sky-scrapers" in Philadelphia, and the City Hall Tower was structurally incompleted.



Girard College, Philadelphia, made from a free balloon using ortho plate and yellow color filter for the first time in aero-photography, July 4, 1893.

Since this initial balloon flight I have made many balloon excursions with my old friend, King, who was a broad-minded, highly-educated gentleman of the old school, with a keen sense of humor, and an ever delightful and entertaining companion.

Late one summer afternoon, having made a number of air-views of Philadelphia to illustrate the rapid development of mid-city real estate, we rose to a great height to watch the sunset, and upon reaching an eastern air-current, slowly floated across the Delaware, and landed, after sundown, in a farm-yard on the outskirts of Camden, where the balloon was made fast to a fence, and we accepted the invitation of the farmer to supper, after which King entertained the pop-eyed farmer boys with cloudland adventures, which he ended by saying: "Well, I declare, its nine o'clock. Better see if anybody has run away with my balloon."



Prof. Samuel A. King and W. N. Jennings preparing for a nocturnal balloon flight at Philadelphia Gas Works.

It was a lovely, calm summer night, and we found the balloon, like a great golden orange, swaying to and fro above the tree tops, under the light of a mellow moon. While helping the pilot to remove stones from the basket, King remarked: "Lots of gas and plenty of ballast. Seems a pity to waste it. How would you like to make a night of it?"

"Try me," I said; then over went bags of ballast and our farmer friends faded out of sight.

"Now, where shall we go from here?" asked King.

"Let us call on Billy Penn," I suggested.

"All right; here goes," said the pilot.

"But you can't steer a balloon," I protested.

"Watch me" was all he said; and sure enough, we moved westward in a direct line with Market Street, and presently hovered straight above the broad-brimmed hat of "Billy Penn"; the rim of arc lights at his feet, and long lines of scintillating street lights giving the impression of a mammoth "Kohinoor" diamond on a ghostly gray background.

"Every time I sail over this section of the city," observed King, "I note a new crop of toadstools. If this 'skyscraper' boom keeps up they will soon be selling real estate down there by the ounce."

Next we saw the moon taking a bath in the shiny waters of the Schuylkill, then slowly drifted over many a main line mansion.

"Suppose we cross the city again," suggested the pilot. "A little sand will do it. Here we go in an upper current. Now the city hall is coming back."

The quaker suit of the founder of Philadelphia had shrunk considerably as we glided over him and followed the twinkling lights of Market Street, again crossing the Delaware, and then striking a northeasterly current that carried us over Bristol and above Trenton, where the red eyes of many pottery furnaces glared up at us.

"Bad place for a forced landing," said King, who was thoroughly enjoying our nocturnal skylark, and was in high good humor. Seated on a sandbag, with his long legs folded up like a jacknife, his elbows resting on the edge of the basket, and his long white beard tucked into his vest opening to act as a chest protector, my companion watched with shiny eyes the lovely lunar landscape. Presently he broke the silence with the remark: "Now we are on an even keel."

"By which you mean?" I queried.

"We have reached a point where the lift of gas and pull of gravity are exactly balanced, and so we are sailing in a horizontal course, neither rising nor falling." "Let me show you a very interesting experiment," he continued. "Here, I will take a piece of tissue paper. Tear it into scraps; and toss them overboard. See how they flutter around us, like butterflies. Now I will throw out a *handful* of sand; and down go our little friends. Watch the aneroid; see, we have risen over a hundred feet. Now I will pull the valve-rope and let out a whiff of gas. Look out; here come the butterflies and up they go out of sight, or rather, we have sunk below them until we slowly get back to normal and meet them again."

Sunrise found us within sight of the Atlantic; with no sign of life except a straw-hatted figure crossing a farmyard, with a cluster of houses ahead.

King manned the megaphone and shouted: "Hallo there?" The hat halted; turned around, and up-tilted. "Where are we?" shouted the pilot. Again, "Where are we?"

And there floated upward in a shrill, piping voice, this reply:

"Up in a balloon, you dern fools."

And three miles of aerial laughter followed.

We landed, light as thistledown, in the still air, on the site of the present Camp Dix, with gas enough to carry us back to Philadelphia, but no wind blowing in that direction.

While steaming homeward in the Philadelphia express, the "Eagle Eyrie" rolled up in the baggage car, my thoughts were still "up in the air." "How many times have you been up in a balloon, Professor?" I asked.

"I really don't know," said my companion: "After I had reached five hundred I stopped counting."

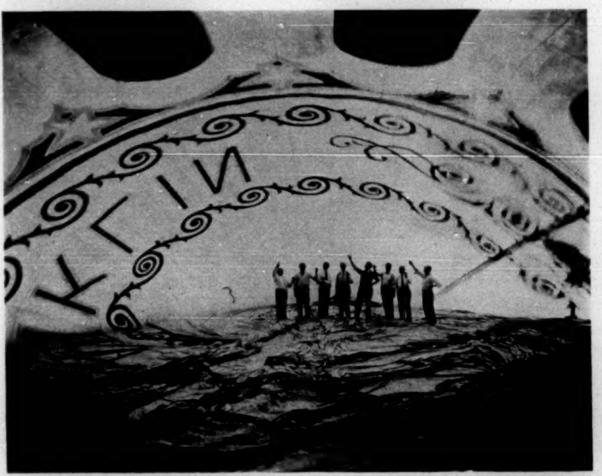
"No serious accidents?"

"None. Only two hair-raising experiences that still disturb my sleep: A fight with the Thunder God, and an encounter with the Goddess of Chance. If you care to hear about it, here goes:

"During the St. Louis Exposition I was engaged to give a series of balloon ascensions. One sultry afternoon I left the fair grounds in a new balloon on a solo flight, to a great elevation where I caught an easterly current that soon carried me over dense woodland, when I saw upon the horizon a crop of mushroom clouds, which meant an approaching thunderstorm. Being unable to find a landing place, and having on hand a good supply of ballast, I decided to rise above and outride the storm. At a height of about five thousand feet I plunged into a region of dense, dark clouds, and presently suddenly emerged, to find myself in an immense cavern or tunnel, lighted by a strange golden glare. For a moment the balloon remained poised midway between the floor and roof of the tunnel; then came a blinding flash and deafening thunder; when the gas-bag was drawn swiftly upward and dashed downward, swinging to and fro, spinning rapidly, and behaving exactly like a pith-ball between electrically charged metal plates. Sparklets played over the netting covering the balloon fabric, and I expected each moment to hear an explosion of coal-gas with which it was charged. While travelling in this zig-zag fashion along the golden cavern, the swinging of the balloon basket grew more violent, and the spinning greatly accelerated, which brought on, for the first time 'air-sickness.' In addition to the up-and-down motion of the aerostat, it was swept onward in a powerful air current, each moment the lightning growing more vivid and the thunder louder. Several

End of our night in the air. New Egypt, N. J.

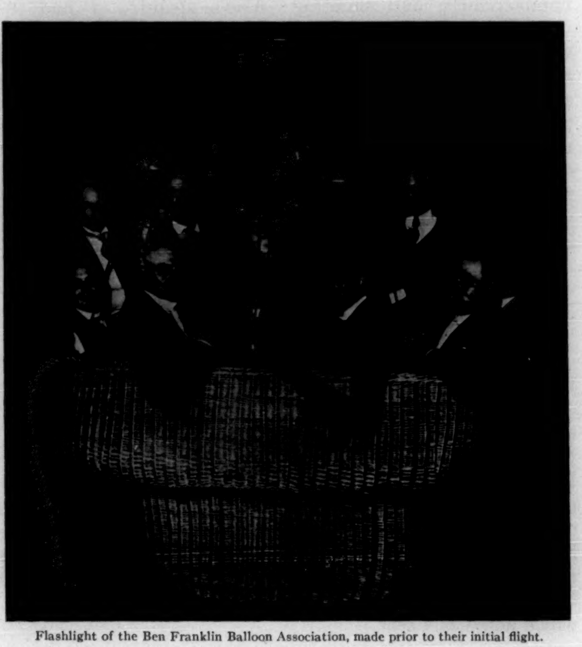
times I was almost thrown from the swinging balloon basket, and had almost given up hope of outriding the storm, when, without warning, the balloon was flung clear out of the tunnel into brilliant sunshine. I had passed between two cloud banks, one snow-white the other dark gray, and from my vantage point I was able to watch the formation of rain. At every discharge of lightning, the electric tension that had kept moisture particles apart, was released, and rain from the lower cloud bank fell in torrents. You may be sure that fifteen minutes later I was mighty glad to drop lightly into a meadow and feel the basket once again touch good old Earth.



Christening the Ben Franklin balloon, 90,000 ft. capacity. The members of the Ben Franklin Balloon Association are standing inside the partly air-filled big balloon. 1907.

"After being spell-bound in cloudland, my next scare was on terra firma.

"As a part of an Independence Day Celebration, I impersonated 'Uncle Sam,' and accompanied by a Boston newspaper man, made a balloon flight from Boston Common on a perfect day; rising straight up into the still air; slowly floating over the Bay, gently sinking until the end of the six hundred foot dragrope trailed over the surface of the water, parallel with the shore line, until we neared a number of Bayshore estates, on the lawn of one of which was a garden party in progress. With the 'Independence' poised directly over the lawn, across which the dragrope was trailing, we were invited to 'drop in and take tea.'



Flashlight of the Ben Franklin Balloon Association, made prior to their initial flight.

"'All right,' I megaphoned, 'pull us down and tie the rope to the fence.'

"This was done and we received a royal welcome when we stepped out of the basket.

"When one of the young ladies expressed a desire to go up in a balloon good-natured banter started, some of the men daring the ladies to go aloft. When I was appealed to by the fair sex I foolishly offered three of them a captive ride, provided the men would operate the dragrope.

"At once the delighted trio started skyward, waving handkerchiefs, and shouting 'Who's afraid?' I had just turned away to reach for a plate of ice cream, when I heard someone say: 'My God!' The wet slippery rope had left the fingers of the men who were paying it out, and the balloon was slowly sailing seaward without a pilot and three helpless passengers. I really think my heart turned over. There was nothing I could do but stand there with my mouth open, mentally cursing myself for my carelessness. A passing motor boat owner waved to us in response to our frantic misunderstood signals, and was soon out of sight. Then occurred a miracle. The balloon began to settle; the dragrope dipped, touched the surface of the water, and came slowly shoreward, soon to be seized by outstretched fingers, and the passengers drawn back to safety, still laughing, waving and shouting 'Who's afraid?' never dreaming they had been in such danger.

"I often wonder what would have happened if Lady Luck had not been so good to a balloonatic and those three angels."

In the spring of 1907, a number of Philadelphia air-enthusiasts formed the "Ben Franklin Balloon Association," the first Aeronautical Society in America, for whom Professor King built the "Ben Franklin" balloon, an eight-passenger, ninety thousand foot gas-capacity aerostat, and in the summer of that year we made our first ascension, with King as pilot, having first partly filled the gas bag with air, crawled through the neck, and held a christening ceremony inside the mammoth balloon. The basket was oval-shaped, with outstanding rim which acted as a seat.

We left the Philadelphia Gas Works at sunset, intending to ride out the gas, and hoping to at least reach Boston or Bangor, according to the prevailing winds. At the height of a mile we gave the craft an external christening, with many an internal gurgle; followed by a celestial chorus, in which the echo of "Sweet Adeline" floated up from the murky depths.

At nine o'clock, King was in the look-out, perched in the suspension ring above us, and suddenly called for silence:

"Gentlemen," he announced, "I am sorry to inform you that we have got to find a landing place at once."

"Why?" we asked in chorus.

"I have been watching the flickering light of a thunderstorm ahead, and we shall soon be in it; so we had better go down at once."

To a man we raised a loud objection to this sudden change of programme, and offered to take a chance of the storm blowing itself out ahead of us; but King was adamant. "Hand me the megaphone," he said, quietly. "We must look out for lights and call for help."

Crowd watching the Ben Franklin Balloonists. 1907. Taken from the balloon.

Again we remonstrated with the pilot and begged him to keep on going ahead, to which he replied:

"I am the pilot of this ship, and responsible for the new balloon and your lives. From past experience I know the folly of a fight with a thunderstorm at night in a gas balloon. The sooner we land, the better I will like it. There, I see lights below. Here goes gas. All hold tight, and don't leave the basket until I give the word."

Then we crashed through an orchard and settled down on the top of an apple tree, from which point King called for help, and soon men appeared with a ladder. But not a moment too soon, for the fury of the storm burst upon us, and it took all our combined efforts to capture the fluttering fabric; roll it up and place it in a barn; then eight half-drowned figures ran through the orchard and sought refuge in front of a big log fire in a near-by farmhouse; where, to the accompaniment of the howling wind and dashing rain outside, together with vivid lightning and crashing thunder, we toasted King and decided he "knew his onions," when next morning we discovered that we had landed within sight of the Atlantic ocean, toward which we had been headed.

There was considerable excitement in the northern section of Philadelphia in the summer of 1910, where ten thousand eyes gazed skyward waiting for the appearance of its first flying machine. Clarence K. Hamilton was on his way from Governors' Island, New York, in a Curtiss Biplane and was now racing a Pennsylvania express train from Jersey City. It was not to be expected that a muslin kite with its 25 horsepower propeller beating against yielding air could keep up with an iron horse, with its ponderous fly-wheels gripping immovable steel rails, with hundreds of horse-power behind them; and the betting was 100 to 1 in favor of the express train. But a great shout went up when the airship came crazily careening over the landing field, with a red-headed, freckle-faced youngster perched on the edge of the lower wing who made a bumpy landing, ahead of the Iron Horse snorting far down the track. Governor Stuart of Pennsylvania was there to felicitate the smiling youngster on his marvellous twenty-five mile an hour flight. That was a great day in the annals of aviation in the city of Philadelphia.

Another great flying event took place in the autumn of the same year, when Grahame White, an English aviator, entertained a crowd at Point Breeze with demonstrations of a Farman Biplane, and J. Armstrong Drexel made a record flight in a Bleriot Monoplane, reaching an altitude of 9,879 feet, and getting lost, shooting twenty miles past the landing place.

I accompanied my old friend "Professor" King to this double event, and he was invited by Grahame White to go aloft in the Farman machine, which invitation the ancient balloonist eagerly accepted. I made a snapshot of the machine when flying about a thousand feet from the ground. Here the old man's cap flew off and jammed the propeller, and only superb skill on the part of the aviator prevented a tragedy.

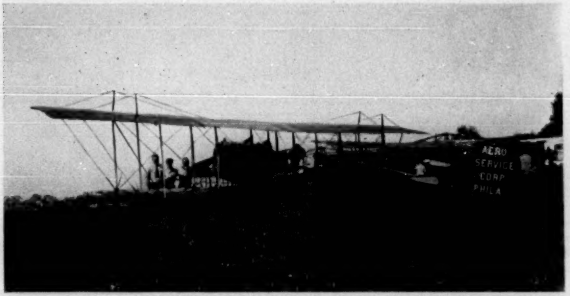
Farman Biplane, Grahame White Pilot, with Samuel A. King, passenger.

"How did you like the ride, Professor?" I asked.

"O shucks!" he snorted. "It's like a windstorm over a boiler factory. Give me a balloon every time."

With the advent of the airplane, which could be flown in any direction regardless of wind currents, I saw a great future for aerial photography, and designed and constructed for that purpose a special cone-shaped 8 × 10 fixed-focus streamlined box camera, with a Multi-Speed-between-the-lens-shutter, which could be operated at 2000/sec.

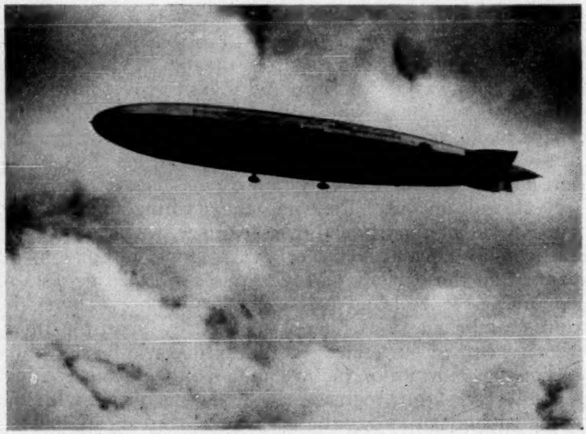
Soon after the formation of the Aero-Service Corporation, I made my first flight in a "Canuck" biplane, with my friend Captain (now Major) Dallin as pilot. In trying out my camera between Philadelphia and Wilmington I made a dozen successful high-speed snapshots. Up to this time the size of plates for aerial photography had been 4″ × 5″ and 5″ × 7″. Now the standard size is 8″ × 10″. A year before this, the U. S. War Department was giving a Flying Demonstration on Belmont Plateau, Fairmount Park. When I begged for a place in the cockpit of an army airplane, I was laughed off the field by an officer who told me it was ridiculous to try to use an 8 × 10 camera for sky-photography. "You won't be able to hold it still enough, and it will pull you out of the cockpit," he said. "Besides that," he continued, "a between-the-lens-shutter is too slow for this work; you need a focal-plane shutter." He would not believe that my multi-speed shutter was far faster than the focal-plane, which I had demonstrated many times.



Major Victor Dallin and W. N. Jennings preparing for a flight.

My outstanding aero-flight was one with Major Dallin, in which we were able to observe two sunsets in one day; one upon landing at the airdrome, and another from above the clouds immediately thereafter, where we reached the "ceiling," chased and photographed rosy-tinted clouds, watching, spellbound, the lovely swift-changing cloudland panorama, until the gasoline gave out and we spiralled down to the landing field.

Not only is the evolution of aviation amazing, but the development of aerial photography is astounding. Since I made the first color-sensitive snapshots from a free balloon on July 4, 1893, the World War has been won—according to Sir Henry Trueman Wood, in charge of British War Photography during that four year conflict—by the art of photography, in which the color-filter and color sensitive plate played an important part, enabling the aviator to detect and destroy camouflage through cloud, mist and battle smoke, which was invisible to the eye of the sky sailer, but clearly recorded by the camera.



ZRIII, later "Los Angeles," flying over Philadelphia. Made from an airplane.

Since that time aero-photography has become so common that on any fine day the sky is dotted with airplanes, from which the cameraman is busy making aerial views of real-estate development, housing conditions, city-planning, industrial plants; and weaving to-and-fro, making maps of a city or its suburbs; the air-survey taking *hours*, while a ground survey of the same region would take *months*.

Admiral Byrd, from his airplane, has charted the Northern and Southern Polar regions; Stevens has furnished infra-red views of mountains *three hundred miles away;* the Marquess of Clydesdale has given us close-up and one hundred-mile-distant views of the Peak of Mount Everest; Colonel Lindbergh has just completed his aerial map of the North Atlantic, and Picard, in a steel-sealed-shell has been carried by a balloon far higher than man has ever flown, in order to capture cosmic rays.

The auto-gyro airplane has great possibilities for the sky-cameraman, who will soon rise from the roof of his newspaper building, sail away several hundred miles to cover interesting news events, which he will develop and print in mid-air, and perhaps make, on his way home, a flexible half-tone printing plate ready to slip in the press upon arrival, his story of the event having preceded him by radio.

Next will undoubtedly come the flashing flight of the stratospheric air-conditioned over-sea liner, which will enable passengers to lunch in New York, take supper in London and breakfast on the Riviera. Movie houses will then be able to keep their news reels up to date, when such events as the Oxford-Cambridge Boat Races, the "Derby" and the International Tennis Tournament at Wimbledon will be shown on the screen of our motion picture houses on the same evening; for in the march of progress man is never satisfied with the accomplishment of to-day; he is always a step ahead, looking for new worlds to conquer, for life is a long, slow climb with many a glorious outlook.

CURRENT-VOLTAGE CHARACTERISTICS OF HIGH POTENTIAL, DIRECT CURRENT BRUSH AND GLOW DISCHARGES IN AIR AT ATMOSPHERIC PRESSURE.

BY

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Yale University.

The measurements to be recorded in this paper were made to fill, in part, a need of data on the current-voltage characteristics at high direct potentials of brush and glow discharges from pointed and spherical electrodes. As will appear, observations of this character are not reproducible with high accuracy and perhaps it is mainly for this reason that systematic data on the subject are not now extant. It is hoped, nevertheless, that the results here presented will be of some service to those working with high voltage, direct current machines. In the experiments which were done, discharge electrodes were used which varied in size from a needle point to a sphere 127 millimeters in diameter. These electrodes were placed opposite a large receiving plane at various distances up to 75 centimeters, and potential differences up to 280 kilovolts were employed.

APPEARANCE AND BEHAVIOR OF THE DISCHARGES.

High potential discharges in air often undergo sudden and marked changes in form without apparent cause. Toepler[1] found, however, that, with a given electrode distance and a constant electrode capacity, each form of discharge is stable over a fairly well defined region of current values, and that unstable conditions obtain for current values bordering on these regions. It may be said in general that the discharge from a positively charged electrode always begins (and ends) as an audible form of brush discharge, consisting of a more or less rapid succession of momentary discharges having the appearance of narrow pencils of light. When the current has increased as a rule to but a few microamperes, although in some cases to as much as 40 microamperes, the brush form suddenly changes into the noiseless glow discharge in which the only light visible is a thin glow covering a considerable area of the electrode surface, amounting to almost a hemisphere for a spherical electrode. After a further considerable increase of current the glow discharge usually changes into the characteristic positive brush form, which, starting from a narrow, bright pencil of light at the electrode, spreads out into a very wide brush which consists of a very large number of fine irregular filaments. Sometimes these filaments fill a somewhat elongated volume which at its base is more than 10 centimeters in radius. The change of the glow discharge into the positive brush often takes place without the slightest noticeable change in the magnitude of the current, and the characteristic curve for one form of discharge appears to be an extension of a like curve for the other form of discharge. In other cases a rise in the current occurs when the positive brush suddenly appears. Owing to the less spectacular appearance of the glow discharge one is apt to underestimate the magnitude of the current in this form of discharge in comparison with that in the brush form of discharge.

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[1] M. Toepler, *Ann. d. Physik* [4] 2, 560 (1900).

When a positive brush or glow current exceeds a certain value, the discharge may of itself, or after the interposition of a wooden stick near the electrode, suddenly change into a sort of arc discharge, named by Toepler a brush-arc. At the onset of the brush-arc, with the static machine used, the current almost doubles in magnitude and the voltage drops. The current now changes very rapidly with change of voltage and in the sense that as the machine is speeded up to increase the current the voltage as a rule diminishes, although this is not true in all cases. The brush-arc starts from the small electrode as a bright narrow pencil of light about two centimeters long, which changes into what appears like a bluish flame that widens to a diameter of 10 to 15 centimeters by the time it reaches the plane electrode when 50 centimeters away, for example. Close eye observations and short time exposure photographs showed the body of the flame actually to consist of innumerable very fine bluish filaments, and examination of the bright pencil of light at the anode in a rotating mirror showed the discharge to be intermittent at a frequency of about 20,000 per second. With large currents, branched sparks emanate from the anode and these at times terminate in the body of the flame itself and at other times extend clear to the cathode, often passing completely outside of the highly ionized region of the brush-arc itself.

A systematic study of the characteristics of this form of discharge was not made and such readings as were taken are not included in the graphs to be shown since this would have necessitated a larger scale of drawing. One numerical example will be cited. Using a 1.40 millimeter wire as an anode, situated 20 centimeters from the plane cathode, the ordinary glow discharge current was 283 microamperes at a voltage of 130.5 kilovolts. Here the discharge suddenly changed into the brush-arc form and the current increased to 636 microamperes while the potential fell to 94 kilovolts. On reducing the current to the lower limit of 240 microamperes, where the arc broke, the potential had increased to 108 kilovolts.

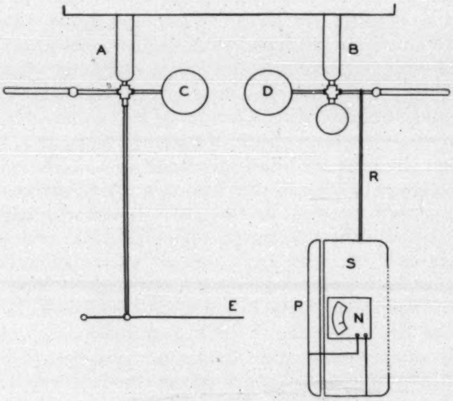
The form of discharge that appears at a negative electrode, before a spark passes, is always a brush discharge. The negative brush differs from a positive brush in consisting of a narrow bundle of light, only one or two millimeters thick, and even at high potentials but 2.5 centimeters long, approximately. Often a negative brush seems to have a considerable number of these pencils of light simultaneously. However, short exposure photographs show only one pencil, indicating that the multiple appearance arises from a rapid jumping about of a single pencil. Moreover when a single penciled discharge suddenly takes on the apparently multiple penciled form the current does not change appreciably. Photographs often show a faint formless flame-like glow at the end of a negative brush, which is not visible to the eye directly.

Negative brush discharges change into spark discharges at much higher potentials than do positive brush discharges.

APPARATUS AND PROCEDURE.

The essential parts of the apparatus used are shown in plan in Fig. 1. The source of electric supply was an electrostatic machine having fourteen glass plates of 81 centimeters diameter, that could be run at high speed. The machine was capable of generating potentials up to 300 kilovolts and of delivering at lower voltages a maximum current of about 800 microamperes. Between the two terminals, *A* and *B*, of this machine were placed the two adjustable spheres, *C* and *D*, the maximum sparking distance between which was used for measuring the potential differences between the discharge electrode *E* and the plane *P*, neither of which was connected to ground. The front portions of the spheres *C* and *D* had radii of curvature of 9.65 centimeters. The spark gap distance could be measured with an accuracy of 0.02 millimeter by means of a cathetometer. The plane *P* was a square piece of galvanized iron, 66 centimeters on a side, which formed one face of a metal box with rounded corners and edges. *P* was electrically insulated from the remainder of the box *S*, permitting the microammeter *N* within, whose terminals were joined to *P* and *S* respectively, to measure the current flowing at any time between *E* and *P*. The combined capacity of the discharge electrode system against the box *S* and against ground was 93.0 centimeters, when the

FIG. 1.



Plan of disposition of apparatus.

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gap between *C* and *D* was 7.5 centimeters and the 0.7 millimeter wire electrode used at *E* was 30 centimeters from *P*.

The plane *P* was sufficiently large to receive practically the whole current flowing from the discharge points *E*, for distances between *E* and *P* up to 50 centimeters. However, when this distance was increased to 75 centimeters it was found, by joining the rod *R* to *P* instead of *S*, that 5 per cent. of the total current from *E* went to *S* at the highest voltages used and a smaller fraction at lower voltages. Since the box *S* was supported on good insulators and as the rod *E* was situated 138 centimeters above the floor, it is believed that even at the greatest discharge distance used practically no current from the discharge point *E* went to objects other than the box. An allowance of one percent has however been made for such possible losses at the highest voltage used. In the results which are given below, these corrections have been applied to the current readings for the 75 centimeters distance between *E* and *P*.

Voltages were computed from the observed spark gap distances by aid of tables given in the International Critical Tables, Vol. VI, page 79, correction being made for pressure and temperature differences.

The measurements were all made during cold weather when the absolute humidity of the air was low, its water content being but 7 or 8 milligrams per liter. Air humidity is said to have no appreciable effect upon the length of the spark that a given voltage will produce between spheres. It doubtless does have some effect upon the magnitude of glow and brush discharge currents. No observations on this effect were here made, and so reference is given to work previously done at lower voltages [2] on the influence of humidity upon discharges from points. The effect there noted may be used to reduce the results to be given to conditions where the air humidity is different.

The procedure followed in making the measurements was to adjust the spark gap between *C* and *D* to some fixed distance and then to increase the voltage gradually by changing the speed of rotation of the static machine until sparking at the above gap occurred, the discharge current being read at the moment of sparking. The first break-down in the spark gap was neglected as it takes place at a somewhat lower voltage than do the succeeding sparks. The light from the brush discharges was found to have no appreciable effect upon the length of the spark gap corresponding to any given discharge current and so no light screen was placed between the two, which were over a meter apart.

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[2] J. Zeleny, *Phys. Rev.*, **26**, 448 (1908).

The discharge electrodes used in the measurements were, (1) a steel sewing needle whose end was ground down to a hemisphere of 0.15 millimeter diameter, (2) a nickel wire with rounded end of 0.635 millimeter diameter, (3) an aluminum wire with rounded end of 1.40 millimeters diameter, (4) a brass rod with rounded end of 4.76 millimeters diameter and (5) brass spheres of 17.4,. 48.2 and 127 millimeters diameter respectively. The needle point was made more blunt than is used for sewing in order to have it maintain a more nearly constant size during a set of observations. Fine steel points gradually disintegrate owing to the oxydizing action of the discharge, the oxide often forming curiously shaped projections on the surface especially during positive discharges.[3]

The rod *E*, Fig. 1, which carried the discharge electrodes at its end, had a diameter of 4.76 millimeters. The greater part of its length was usually covered with a glass tube to prevent spurious discharges from its sides. With spherical electrodes this glass tube extended up to the rear portion of the spheres and all such discharges were effectively eliminated. When the rounded end of the support rod itself was used as an electrode, there was a tendency, with the higher potentials used, for brush discharges to form at the end of the protecting glass tube, a difficulty which could not always be removed by sealing the glass tube to the rod with a smooth layer of wax. The 1.40 millimeter wire electrode was usually covered over its whole length of 20 centimeters, up to within 6 millimeters of its end, with a tightly fitting glass tube having a wall of 0.7 millimeter thickness. To carry the needle points and the 0.635 millimeter wire, the support rod was gradually tapered to an angle of about 17° at its end where an axial hole had been bored just large enough to take the small diameter electrodes. These electrodes were allowed to protrude from 5 to 7 millimeters beyond the end of the support rod, and, notwithstanding the tightness of the fit, it was not always possible to prevent the formation of small brush discharges at the exposed juncture of the electrode and support rod.

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[3] J. Zeleny, *Phys. Rev.*, **26**, 137 (1908). H. T. Barnes and A. N. Shaw, *Proc. Roy. Soc.* [A] **82**, 336 (1909).

RESULTS.

The experimental results are represented by the curves in Figs. 2 to 13 inclusive. The points on these curves show all of the observations which were taken intermittently over a period of several months. In many cases, the same electrode was repolished, set up with altered guards against lateral discharges, and used on different days. Each point on a curve gives the average of about three quite concordant readings taken in succession. Readings taken on different days are distinguished by being differently marked. When the observations, taken on different days with the same electrode, show a different trend two separate curves are drawn, one as a broken line. The currents given in milliamperes are plotted in the curves as ordinates against the corresponding potential differences in kilovolts as abscissas. The number on each curve gives in centimeters the distance between the end of the electrode and the current receiving plane.

The variation in the results shown for observations taken at different times are not wholly due to experimental errors. They did not show any correlation with changes in pressure, temperature or humidity of the air. They must be considered as arising from unknown causes not under control.

As a rule no attempt was made to find the voltages at which the brush discharges began nor their values for currents below a few microamperes. In a few cases readings were taken with currents as low as 0.1 microampere, examples of which are found in Figs. 8 and 10 for the electrode distance of 75 centimeters. These curves show how slowly, especially at the start, the current increases with increase of voltage for this large distance between the electrodes.[4]

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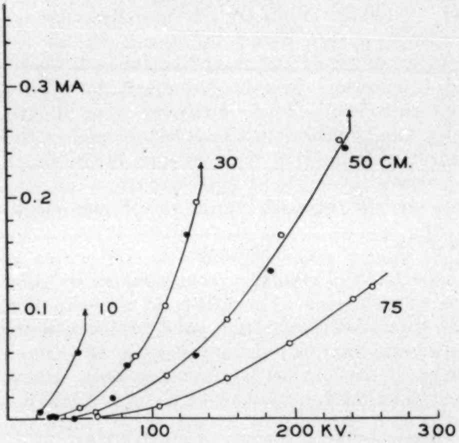
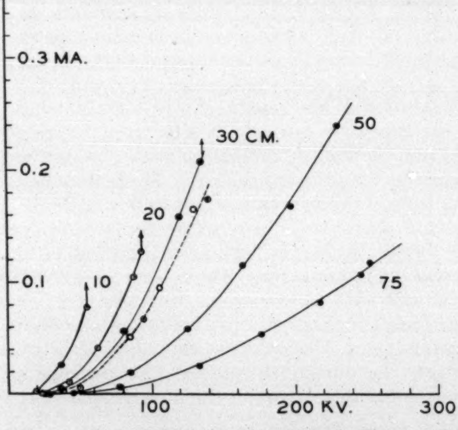
[4] See also O. Hovda, *Phys. Rev.*, **34**, 25 (1912).

FIG. 2.



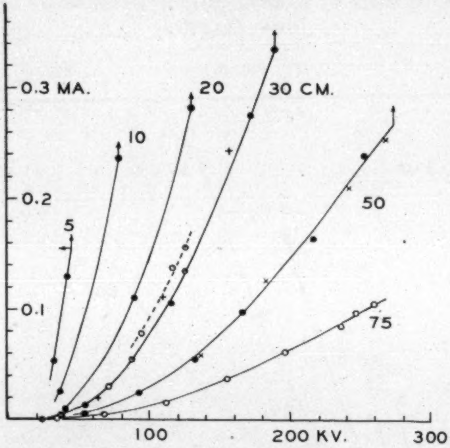
Positive discharge. Steel sewing needle. Diameter of end, 0.15 mm. For d = 10 cm., glow discharge. For other distances, glow discharge up to 15–30 microamperes and brush discharge with larger currents.

FIG. 3.



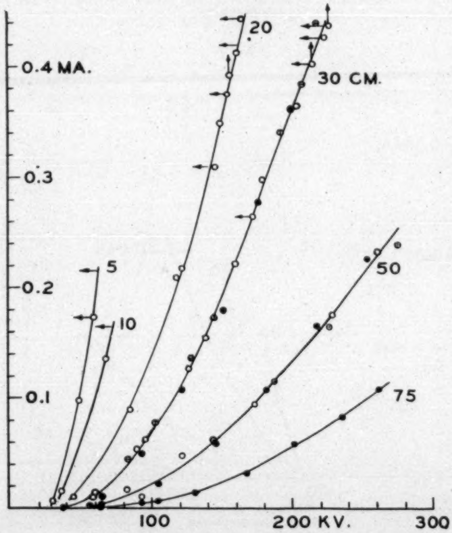
Positive discharge. Nickel cylindrical wire with rounded end. Diameter, 0.635 mm. Glow discharge up to about 30 microamperes and brush discharge with larger currents. Marked disagreement at d = 30 cm. where readings taken on different days overlap.

FIG. 4.



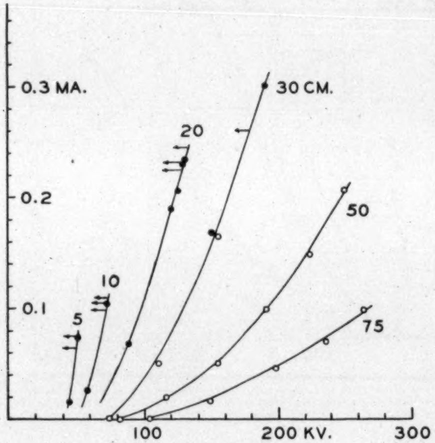
Positive discharge. Aluminum cylindrical wire with rounded end. Diameter, 1.40 mm. For d = 75 cm., glow discharge which changed to brush discharge at 30 microamperes. For other distances glow discharge only except that broken line on d = 30 cm. represents brush discharge.

FIG. 5.



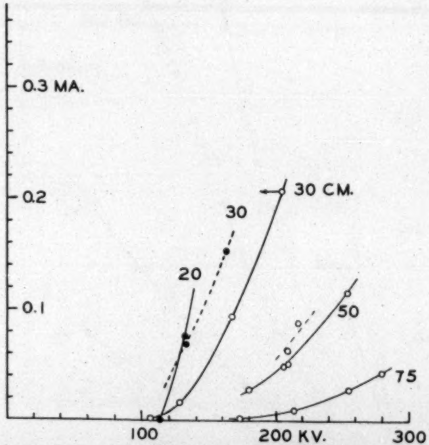
Positive discharge. Brass cylindrical rod with rounded end. Diameter, 4.76 mm. Glow discharge, except below 2 microamperes.

FIG. 6.



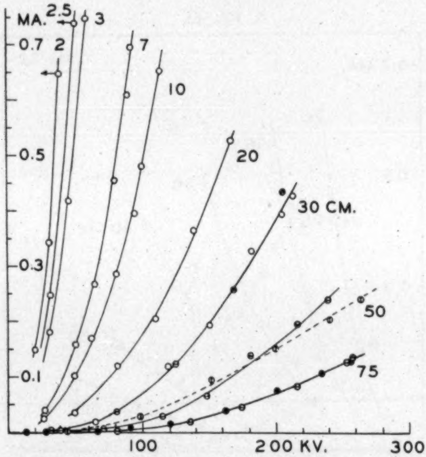
Positive discharge. Brass sphere. Diameter, 17.4 mm. Glow discharge, except below 30-40 microamperes.

FIG. 7.



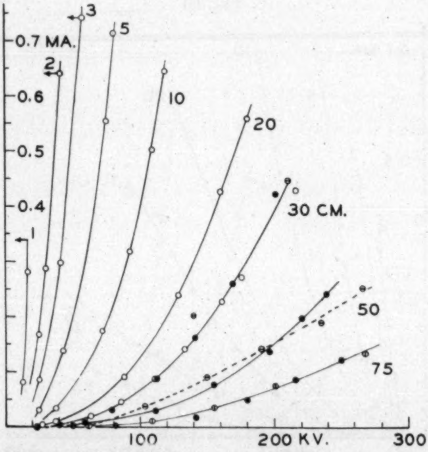
Positive discharge. Brass sphere. Diameter, 48.2 mm. Full lines, glow discharge. Broken lines, brush discharge.

FIG. 8.



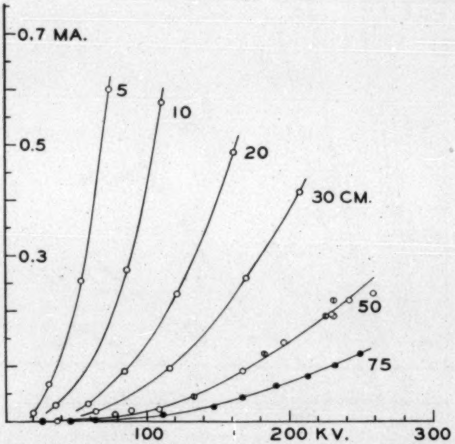
Negative discharge. Steel sewing needle. Diameter of end, 0.15 mm.

FIG. 9.



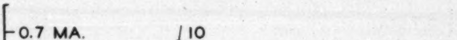
Negative discharge. Nickel cylindrical wire with rounded end. Diameter, 0.635 mm.

FIG. 10.



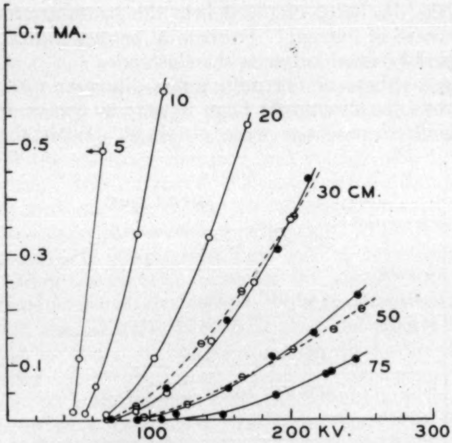
Negative discharge. Aluminum cylindrical wire with rounded end. Diameter, 1.40 mm.

FIG. 11.



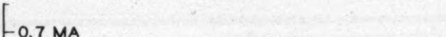
Negative discharge. Brass cylindrical rod with rounded end. Diameter, 4.76 mm.

FIG. 12.



Negative discharge. Brass sphere. Diameter, 17.4 mm.

FIG. 13.

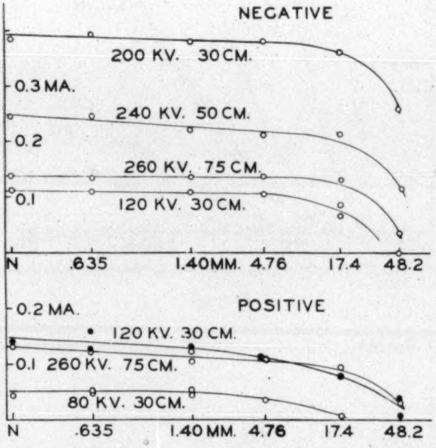


Negative discharge. Brass sphere. Diameter, 48.2 mm.

A vertical arrow on a curve indicates that at the point marked the discharge changed into the brush-arc form with large increase of current. Horizontal arrows indicate places where sparks passed between the electrodes.

When a sphere of 127 millimeters diameter was used for an electrode the discharges from it were so erratic that only a few isolated readings were obtained. With the sphere charged negatively and placed 20 centimeters from the plane electrode, a long narrow brush discharge appeared at 221 kilovolts. At 225 kilovolts the average current flowing was 305 microamperes and the discharge consisted of an intermittent, spitting brush through which a spark passed now and then almost to the anode. On increasing the electrode distance to 30 centimeters, the negative brush discharge commenced at 274 kilovolts. When the sphere was charged positively and the distance between the electrodes was 30

FIG. 14.



Variation of current with diameter of electrode. Currents in milliamperes plotted as ordinates against diameter of electrodes plotted as abscissas on logarithmic scale. For each curve, the potential difference in kilovolts and the electrode distance in centimeters had the constant values shown. Positive discharge below, negative above.

centimeters, the only discharge obtained was a mixture of glow, brush and spark discharges for which no definite readings could be obtained.

Figure 14 has been drawn from data gathered from Figs. 2 to 13 to show the dependence of the current flowing during a glow or brush discharge upon the dimensions of the discharging electrode under stated conditions. Each curve shows, for the electrode distance and voltage given, the relation between the currents, expressed in milliamperes, as ordinates and the size of the electrodes expressed in millimeters on a logarithmic scale as abscissas. The *N* stands for needle point. It is apparent that over a very considerable range of sizes the current decreases but slowly with increase of the dimensions of the point. This result invalidates the impression that is quite prevalent that the tips of lightning rods must be sharp to enable them to discharge electricity effectively.

I wish to acknowledge here the valuable help received throughout the work from my assistant, Dr. C. D. Bock.

Rhenium-Plated Acid Containers.—(Science Service.) Rhenium, a rare element, was discovered as early as 1925 by Naddack, a German chemist, who named this new metal after the river Rhine. It has been known, almost from the time of its discovery, that rhenium is very resistant to hydrochloric (muriatic) acid. On the other hand, it was only at the last meeting of the Electrochemical Society that PROF. CALIN G. FINK and P. DEREN of Columbia University announced the discovery of how to plate rhenium on brass, copper and other metals.

Such a discovery may prove of the greatest importance to industry. Unlike nitric and sulphuric acids, which can be shipped and stored in suitable metal containers, hydrochloric acid has necessitated the more costly method of transporting and storing in glass bottles protected by heavy wooden containers. Now it would appear that the acid can be shipped cheaply in tank cars lined with rhenium and stored in rhenium-plated tanks.

While rhenium is widely distributed in the earth's crust, no deposits have so far been located which yield more than a trace of the metal. Even in the richest ores it is there only in from 2 to 20 parts per million. Present in the slime waste products from copper refining plants in about one part per million, rhenium may be classed as a by-product up to that point. From there on, pure rhenium may be obtained from such copper wastes at a cost which makes its price nominal.

C.

PHOTOMICROGRAPHY AND RADIATION STUDIES WITH VARIOUS WAVE-LENGTHS OF MONOCHROMATIC ULTRAVIOLET RADIATION.*

BY

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INTRODUCTION.

A microscope with an all-quartz optical system was designed by Doctors Köhler and Von Rohr (1 and 2) of the Carl Zeiss Scientific Staff. Its original purpose was to attain a higher resolving power by using the shorter wave-lengths to which the glass optical systems are opaque. It has, however, other important uses. Such a microscope equipped with a quartz monochromator and a suitable source of ultraviolet radiation enables one not only to obtain microphotographs of high resolving power but also to study the absorption of various parts of microörganisms to various wave-lengths of visible and ultraviolet radiation. That is, it enables one to determine roughly the absorption spectrum of microscopic parts. It can be used to study the effects of these radiations on the organisms while they are under the microscope and to correlate the radiation effects with the absorption.

The selective absorption of the microscopic parts produces a staining effect which enables a better study of the structure of living or unstained organisms (1 to 7).

Lucas has used the ultraviolet microscope for micro sectioning (3). Wyckoff and Ter Louw, by using a Barnard instrument adapted to take Zeiss optics and modified in various minor details, have been able to take sufficiently short exposures to eliminate the destructive action of the ultraviolet radiation on the organisms (3 and 4). This is important because it has been impossible for us to obtain satisfactory microphotographs of certain living organisms, due to their sensitivity to the ultraviolet radiation; swelling, sometimes to the bursting point, occurs in a few seconds' exposure.

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* Read before the American Chemical Society, 82d meeting at Denver, Aug. 1932, and before the 2d summer Conference on Spectroscopy and Its Applications, George Eastman Research Laboratory for Physics, Massachusetts Institute of Technology, July 17, 1934.

A great deal of work has been done on the biological effects of ultraviolet radiation. Recently comprehensive reviews of the literature and some interesting and important results have been published (8 to 16). Further reviewing in this publication seems unnecessary.

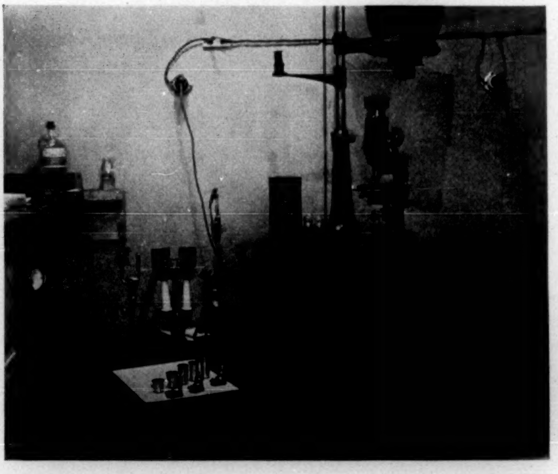
The mechanism by which ultraviolet radiation is able to produce biological effects is of interest to cancer research workers because of the probable relation to the mechanism by which X-rays and Gamma-rays are effective in the treatment of cancer. It is quite possible that the effectiveness of the X-rays and Gamma-rays is due partially if not entirely to the secondary ultraviolet radiation which they generate in the immediate environment of the living cells. The proof of this postulate is at present being sought in this laboratory. An excellent review "Biological Effects of Short Radiations," has recently been published by Packard (17).

DESCRIPTION OF APPARATUS.

The apparatus (see Fig. 1) in the Cancer Research Laboratories is practically the same as that used and clearly described by Lucas (5) except for certain changes. Instead of a cadmium or magnesium spark a small mercury arc (see Fig. 2) serves as a source of ultraviolet radiation. Its advantages are that it has a number of well separated intense lines throughout the visible and ultraviolet spectrum regions which enables the taking of a series of photomicrographs with these lines. To facilitate selecting the desired wave-length a pointer and wave-length scale can be attached to the monochromator part of the apparatus which, when once calibrated, allows any wave-length to be quickly directed into the condenser of the microscope. The lens system is not achromatic, consequently it is necessary that the monochromator lens as well as those of the microscope be focused for each wave-length setting. A fluorescent screen placed on the diaphragm of the condenser enables the focusing of the monochromator. To determine the proper microscope setting for each wave-length it is convenient to plot a curve with wave-lengths as abscissa and readings of the fine adjustment focusing screw as ordinate (see graph Fig. 3). The readings for the curve are obtained as follows:

Set the pointer of the monochromator on, say, the 4350 Å. mercury blue line and focus the blue image of the arc on the diaphragm of the condenser. Focus the microscope on the object in the usual manner as is done with the ordinary visible microscope. Note the setting of the fine adjustment focusing screw. Next set the monochromator for the 4047 Å. radiation which is in the violet region of the spectrum and still visible. Focus the arc image on the condenser. Then move only the fine adjustment screw until again a sharp image is obtained. Note the new reading of the screw. Repeat the above after setting on the 3654 Å. line. Since this radiation is invisible, the focusing eyepiece supplied by the Zeiss Company must then be used for an approximate focus. By taking one or two

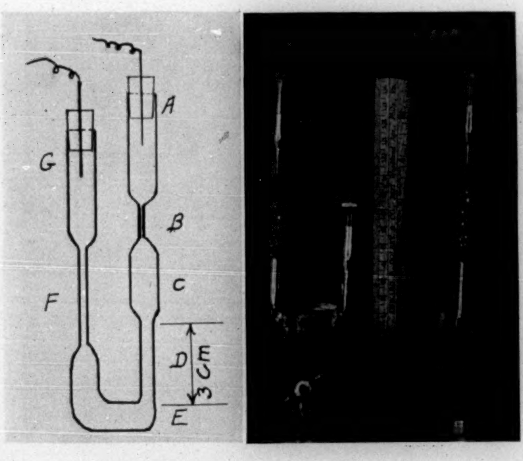
FIG. 1.



The quartz microscope.

pictures on each side of the approximate focus and extrapolating, the correct reading of the fine adjustment screw can be determined. The same procedure is again followed for the 3332 Å., 3132 Å., 3028 Å., etc. The correct readings of the fine adjustment screw are then plotted against wave-lengths and a smooth curve can be drawn through the points. This curve is similar to an index of refraction curve. Thus if one wishes to take a picture with any wave-length in the ultraviolet region he has only to focus with the 4350 Å. or 4047 Å. visible radiation and refer to the graph for the number of divisions the fine adjustment screw must be turned for the proper focus. The monochromator is adjusted for that line and the picture taken. The proper exposure time and diaphragm stop must also have been predetermined. A separate focus curve must be drawn for each objective.

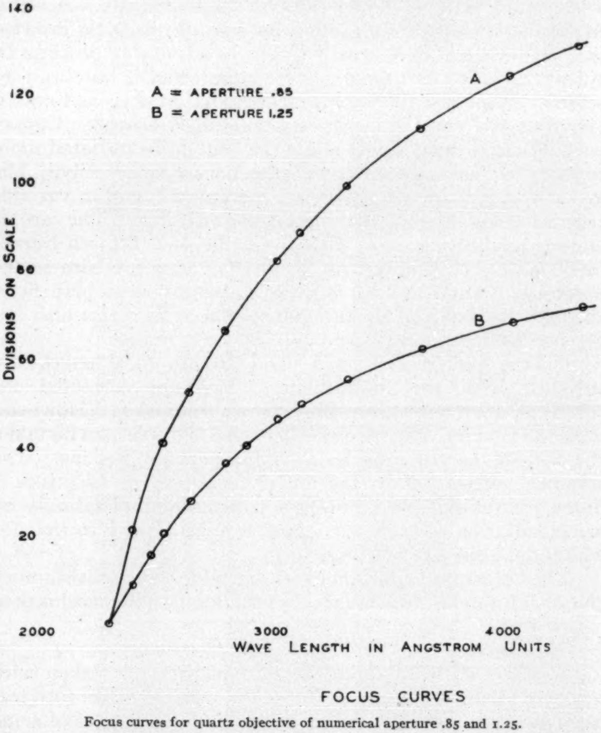
FIG. 2.



Mercury arc used as a source of ultraviolet radiation.

The small mercury arc used as a source of ultraviolet radiation in these experiments has proved to be exceedingly convenient for many experimental purposes and will therefore be described (see Fig. 2). A quartz tube 25 cm. long with a bore of about 8 mm. is pulled down to about .5 mm. bore at *B*.

FIG. 3.



Focus curves for quartz objective of numerical aperture .85 and 1.25.

This is done to prevent the arc from oscillating. The tube is then pulled down to 3 to 4 mm. at *D* which is the part in which the arc is maintained. The tube is again pulled down at *F* to a 1 to 2 mm. bore. This construction serves to diminish the heat conduction to *G*. The tube is then bent into the convenient shape shown in the figure. If so desired the bending may be altered so as to make the arc tube *D* horizontal instead of vertical. The tube is then filled with very clean mercury and heated until all the air bubbles are boiled out. A tight-fitting cork stopper containing an iron electrode is inserted into *B*. A small iron stove bolt serves admirably and can be turned down so as to expand the cork when it has been inserted. A loose-fitting stopper is inserted at *A* so as to allow air to escape when the mercury column is heated. Copper wire wound around *C* will allow the heat to be radiated more rapidly and cause the arc to operate more satisfactorily. The arc is operated in series with a 1.5 ampere 100 ohm variable resistance on a 110-volt direct current line. The arc is started by heating at *D* with the flame of a Bunsen burner until the mercury is separated by the vapor pressure of the mercury. When the arc is struck about one ampere flows through the lamp. An inductance placed in series also improves the operation of the lamp.

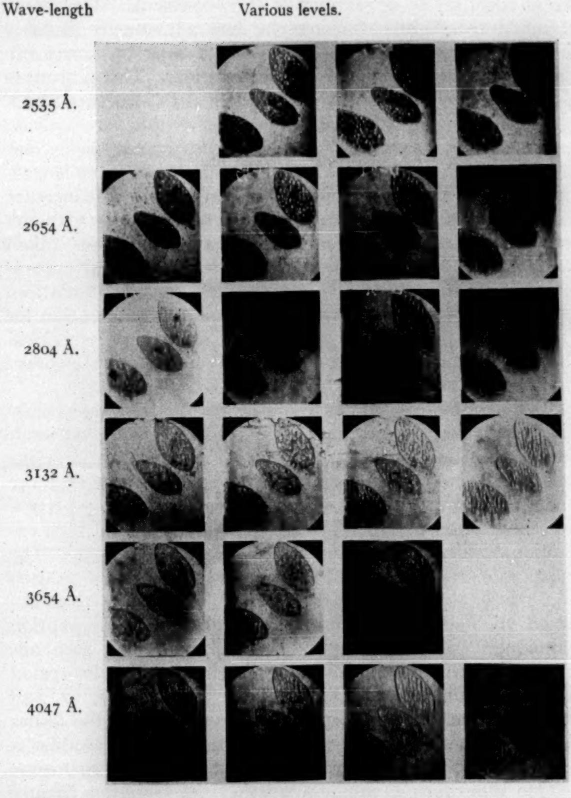
Quartz objectives of 1.7, 2.5 and 6.0 mm. focal lengths are supplied with the instrument. They are corrected for spherical aberration only for 2740 Å. radiation. However, with the 1.7 mm. objective excellent photographs can be taken throughout the visible and ultraviolet spectrum regions. The spherical aberration for the longer focal length objectives is much greater and good photographs can be obtained only by using radiation whose wave-length is approximate to that for which the objective was designed.

The Leitz quartz dark field cells provide a very satisfactory chamber for mounting living cells for microscopic examination.

EXPERIMENTAL RESULTS.

Figure 4 shows a series of photomicrographs taken with a 1.7 m. quartz objective and a No. 10 eyepiece (original magnification 1500 reduced in printing to about 150) of some euglena which had just previously been killed with 2535 Å. radiation. Euglena were chosen as cells for study because they are motile organisms, easy to maintain and comparatively simple in structure. They were also the only protozoa exam-

FIG. 4.


Wave-length
Various levels.
2535 Å.
2654 Å.
2804 Å.
3132 Å.
3654 Å.
4047 Å.

Photomicrographs of euglena with various wave-lengths of ultraviolet radiation. Original magnification 1500 ×, 1.7 focal length, 1.25 N.A. objective and No. 10 eyepiece.

ined which did not swell and burst under the influence of ultraviolet irradiation. The horizontal rows are photomicrographs taken with the same wave-length of radiation but showing different focal levels or sections of the organisms. They were obtained by slightly turning the fine adjustment focusing screw, a process called microscopic sectioning by Lucas (5). Each level is less than .001 mm. separation. This procedure also tends to eliminate any ambiguities as to structure which sometimes arise due to focus variations.

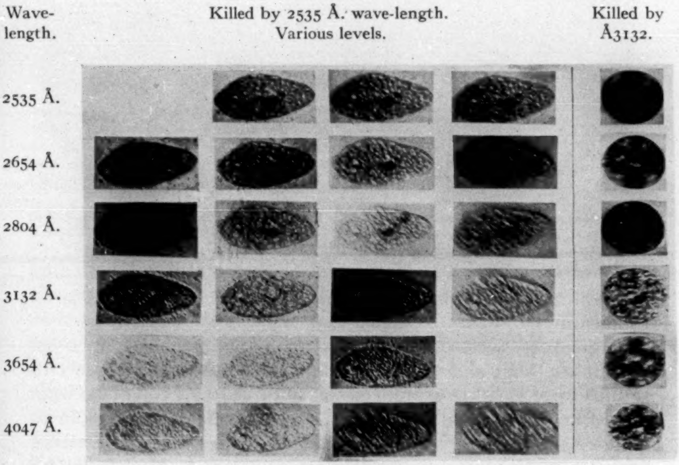
The vertical columns are photomicrographs having approximately the same focal level but differing in wave-length. Column two contains the pictures in best focus. The increase in resolving power (clearness of structural detail) with decreasing wave-length is easily noticeable. Pictures taken with 2535 Å. radiation show marked clearness of structural detail compared to those taken with 4047 Å. radiation. Though the objective is corrected for spherical aberration for 2750 Å. radiation there is little if any indication of spherical aberration though the departure from this value is considerable. Also note Fig. 7.

In the top three rows the nuclei of the cells are plainly visible while in the bottom three rows they are entirely absent. This simply means that the nucleus is opaque to radiations shorter than wave-lengths 2804 Å. and transparent to those longer than 3132. In other words, the nucleus is made up of a molecular material which has an absorption band of high extinction coefficient at wave-lengths from 2804 to 2535. The quartz monochromator and microscope can therefore be used as a micro absorption spectrograph. The results thus obtained are in agreement with the regular macro absorption technique. Myrback, Euler and Hellstrom (18) give absorption curves of some nuclear proteins having absorption bands extending from 2700 to 2000 Å. (See also 11, 12, 13.) Due to the selective absorption of the nucleus in the upper three rows a staining effect is produced and this enables a better study of the structure of living or unstained organisms.

One immediately wonders whether the Grotthus-Draper Law is applicable to the killing of euglena, i.e., are only those rays which are absorbed effective in killing cells? To a limited extent it does hold, for wave-lengths 2535, 2654 and

2804 Å. are exceedingly lethal. Wave-length 3654, 4047 Å. and other visible radiations are not lethal. However, the wave-lengths 3132 and 3028 Å. do appear to have an effect which is different from either the shorter or longer wave-lengths. Curiously these wave-lengths are the limiting ultraviolet rays which reach us from the sun. They are the ones which activate vitamin *D* and produce sun burns. When euglena are irradiated under the microscope with these wave-lengths they soon go into a spherical form, cease to move and are apparently dead. See right-hand column of Fig. 5. The euglena were attracted to these radiations even though they apparently perished in it, while they were indifferent to the longer wave-lengths and very much repulsed by the shorter ones. If this rounding-up phenomenon is the result of a selective absorption of wave-lengths 3132 and 3028 Å. it is not readily apparent from the photographs taken with these wave-lengths.

FIG. 5.



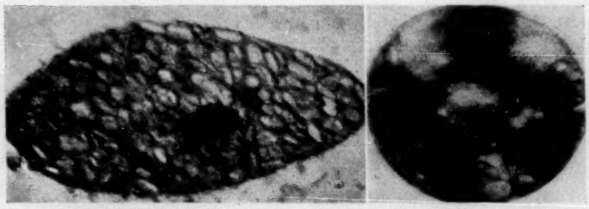
Photomicrographs of euglena with various wave-lengths of ultraviolet radiation. Original magnification 1500×.

It is interesting to note that once the organism has been killed the further irradiation necessary to take the photomicrographs was not sufficient apparently to change the structure of the organisms.

Figure 5 is a series of photomicrographs taken under the same conditions as those in Fig. 4 except the cells in the right-hand column were killed with 3132 Å. radiation.

To show more detail two unreduced photomicrographs are shown in Fig. 6 taken with 2535 Å. radiation. The left one was killed with 2535 Å. radiation, the right one with 3132 Å. radiation.

FIG. 6.

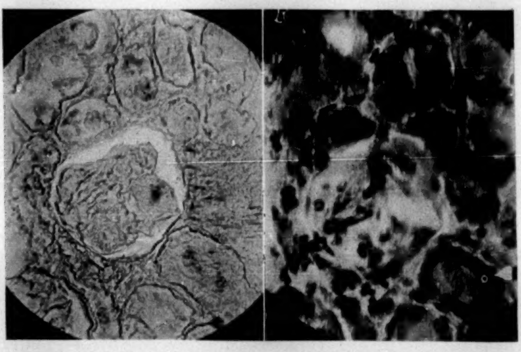


Photomicrographs of euglena taken with 2535 A. radiation. The one on the left was killed with 2535 A. radiation and the one on the right with 3132 Å. radiation. Magnification 1500 × — 1.7 focal length objective.

Attempts were made to obtain photomicrographs of paramecia, colpoda, and entosiphon but under the influence of radiation of shorter wave-lengths than 2900 Å. the organisms would begin to swell and burst, which made it impossible to secure a satisfactory series of pictures. A series of interesting micro moving pictures, however, were taken to study the cell destruction processes of the ultraviolet radiation (19).

In Fig. 7 are two microphotographs of identically the same slices of unstained mouse kidney tissue. The left one was taken with 3132 Å. ultraviolet radiation and the right one with 2535 Å. ultraviolet radiation. The absorption of the nucleus of the 2535 Å. radiation is strikingly obvious and gives the appearance of a stained piece of tissue. The increased resolving power also gives considerable structure in the nucleus and cell structure. The photograph on the left is of value in studying the cell structure.

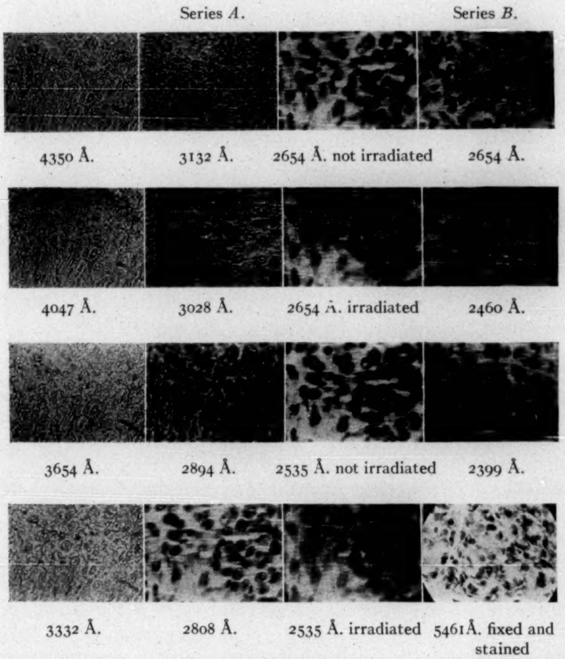
FIG. 7.



Photomicrograph of the same section of mouse kidney. The one on the left was taken with 3132 Å. radiation and the one on the right with 2535 Å. radiation. Original magnification 1200 ×, reduced to 500 ×.

In Fig. 8 are two series of unfixed and unstained sections of rat sarcoma. The tumor tissue was removed from a living rat and the photomicrographs taken within a few minutes after the removal of the tissue. This was done to enable making observations of the cells in as near a living condition as possible. The sections were cut on a freezing microtome and placed in a normal saline solution in a quartz dark-field chamber. The absorption of the radiation begins at 2894 Å. and reaches a maximum at 2500 to 2600 Å. and becomes less again at 2399 Å. The photograph in the lower right-hand corner is a fixed and stained section of the same tissue and photographed with green light. This approximates the regular procedure of taking photomicrographs. A comparison with the other photographs shows that in fixing and staining a considerable change has taken place. The photographs in series *A* are all of the same piece of tissue. There are, however, two taken with 2535 Å. and two with 2654 Å. radiation. The lower one of each pair has been irradiated for about 2 hours with 2535 Å. radiation. A considerable change has taken place especially in the degree of absorption (the opacity) of the extra-nuclear material to those radiations. The photographic plates are under-exposed though the exposure time was increased three fold. No change was noticeable after an exposure of five minutes, consequently the changes due to the amount of radiation necessary to take the photomicrographs are probably not important. Series *B* is a section of the same tumor photographed 6 hours after preparation. The two

FIG. 8.

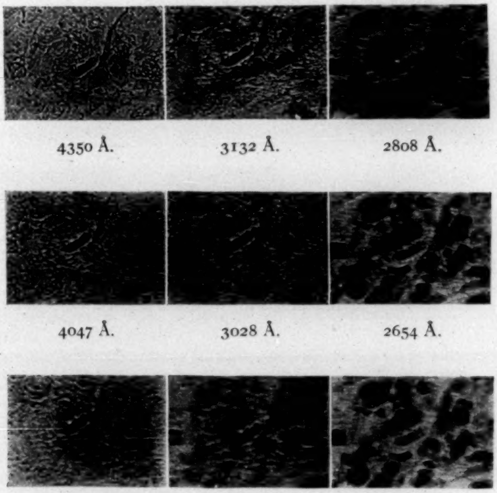

Series *A*.
Series *B*.
4350 Å.
3132 Å.
2654 Å. not irradiated
2654 Å.
4047 Å.
3028 Å.
2654 Å. irradiated
2460 Å.
3654 Å.
2894 Å.
2535 Å. not irradiated
2399 Å.
3332 Å.
2808 Å.
2535 Å. irradiated
5461 Å. fixed and stained

Photomicrographs of unstained sections of rat sarcoma (a form of cancer). Original magnification 1200 ×, reduced to 200 ×.

photographs taken with 2654 Å. radiation are very much alike, showing that reproducible results are obtainable.

In Fig. 9 is another series of rat sarcoma photographs of the same tissue slice, showing the changes in absorption which take place with change in wave-length. Figure 10 is a similar series of mouse spleen.

FIG. 9.



4350 Å. 3132 Å. 2808 Å.

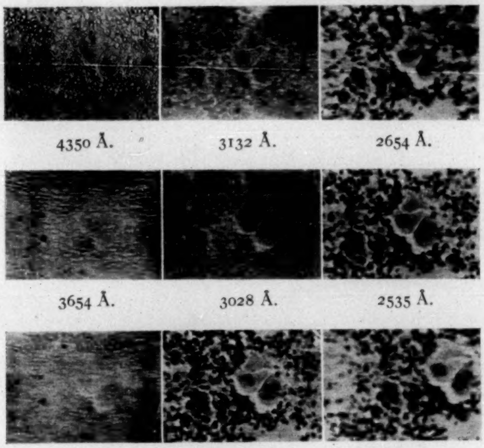
4047 Å. 3028 Å. 2654 Å.

3654 A. 2894 Å. 2535 Å.

A series of photomicrographs of rat sarcoma (a form of cancer). Original magnification 600 ×, reduced to 100 ×.

Since this paper has been prepared for publication an interesting article by Lucas (20) has appeared, on the ultraviolet absorption of the various parts of living cells as determined by the quartz microscope, and the changes produced by the action of various wave-lengths on these cells as shown by series of photomicrographs.

FIG. 10.



4350 Å. 3132 Å. 2654 Å.

3654 Å. 3028 Å. 2535 Å.

3332 Å. 2808 Å. 2460 Å.

A series of photomicrographs of mouse spleen. Original magnification 500×. reduced to 90×.

SUMMARY.

1. The all-quartz monochromator and microscope can be used as a micro absorption spectrograph to determine roughly the visible and ultraviolet absorption spectra of microscopic parts.

2. It can be used as an instrument for observing the irradiation effects of various wave-lengths of visible and ultraviolet radiation while the organisms are being irradiated.

3. A correlation between absorption and irradiation effects can be made.

4. It provides a method of obtaining more than one picture of the same piece of tissue thus enabling a more thorough study of the tissue structure.

5. Living or unfixed tissue can be better studied due to the staining effect produced by the selective absorption of the shorter wave-lengths. This also enables the elimination of the changes due to the fixing and staining process.

6. The resolving power of the microscope is great.

7. A convenient source for obtaining a series of wavelengths of monochromatic ultraviolet radiation is described.

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ON THE NATURE OF LIGHTNING DISCHARGES.

BY

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INTRODUCTION.

In a previous paper [1] we gave a preliminary account of the experimental methods of determining the discharge characteristics of lightnings. The work was executed by the author during thunderstorms, which were observed in summer seasons at a research station erected for this purpose near Uppsala. The proper impulse to these researches came from our earlier measurements of the electrostatic fields in thunderstorms. These researches were executed during the years 1919–22. At these investigations horizontal antenna wires were used and we observed besides slow moving variations in the electrostatic field also very rapid and characteristic ones caused by more or less distant lightning discharges. We had no possibility of analysing these rapid variations exactly by the slow recording electrostatic voltmeters, which were used in the mentioned measurements.

It was obvious that the observed rapid variations in the electrostatic fields caused by lightnings, necessitated instruments of a very high speed-time recording sensitivity and it seemed possible to try to use cathode ray oscillographs of special construction in such an application. In some preliminary experiments about this matter we stated that the only method to avoid fogging of the film when using a cathode ray oscillograph was to work with an earthed antenna circuit. This had to be specially arranged and with the circuit reacting only for a voltage variation during the time of passage of the emitted lightning impulse.

A cathode ray oscillograph fitted to realize this condition had to be connected above a resistance in a damped antenna circuit. The passage of a lightning impulse above the antenna system resulted in such a case in voltage variations above the resistance of the circuit, which could easily be recorded by the cathode ray oscillograph. Observations of this kind without objections had obviously to be performed with a circuit the time constant of which had to be small in comparison with the duration of the lightning discharge.

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[1] Harald Norinder: "Some Electrophysical Conditions Determining Lightning Surges." JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 205, No. 6, June 1928.

The first and preliminary results of the method were obtained as early as in the summer of 1921 when we used visual observations by the aid of the fluorescent screen of a Braun tube. At that time it was stated that lightning in general consisted of a set of discharge pulses. The lightning discharges showed themselves by closer observation to be very complicated and in some of their important details very rapid. It was thus from our experience impossible to measure these rapid variations exactly by visual observations on a fluorescent screen of a cathode ray tube. The visual observations proved to have a more qualitative value and our efforts became at an early stage of the research work concentrated upon the construction of a special type of cathode ray oscillograph fitted to record the impulses from lightning discharges.

The most prominent difficulty for such an instrument was to prevent a fogging of the photographic filmlayer within the tube of the oscillograph. This difficulty became very pronounced by the impossibility of forecasting the time of arrival of a lightning discharge during a period of observation. The author [2, 3] solved this problem by an application of the electron beam of the cathode oscillograph in a kind of relay function

Figure 1 will in such a case illustrate the arrangements used and with following indications: (1) cathode, (2) anode, (3–5) relay circuit, (4) target, (6) radiation shield, (7) time circuit, (8) film, (9) potentiometer. During the time, which was necessary for the development of such a special oscillograph, visual observations on the characteristics of lightning

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[2] O. Ackermann: "A Cathode Ray Oscillograph with Norinder Relay." Presented at the Winter Convention of A. I. E. E. New York, N. Y., Jan. 27–30, 1930.

[3] H. Norinder: "Ein besonderer Typus des Kathodenoscillographen." *Zeitschrift für Physik*, **63**, 9–10. Berlin 1930.

discharges with a Braun tube were still continued and proved to be very helpful to the definite construction of the instrument.

The first records of the specially constructed cathode ray oscillograph were obtained as lightning surges on a transmission line in 1925.[4] During the next following years a number of lightning pulses and surges were recorded on transmission lines and antenna circuits.[5]

FIG. 1.

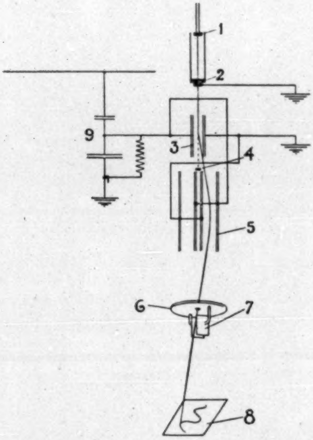

Plate system of cathode ray oscillograph.

The cathode ray oscillograph in the meantime was considerably improved in its experimental details and Fig. 2 illustrates some of the improved oscillographs used in the thunderstorm researches of this paper.

In spite of the rare occurrence of lightning in Sweden

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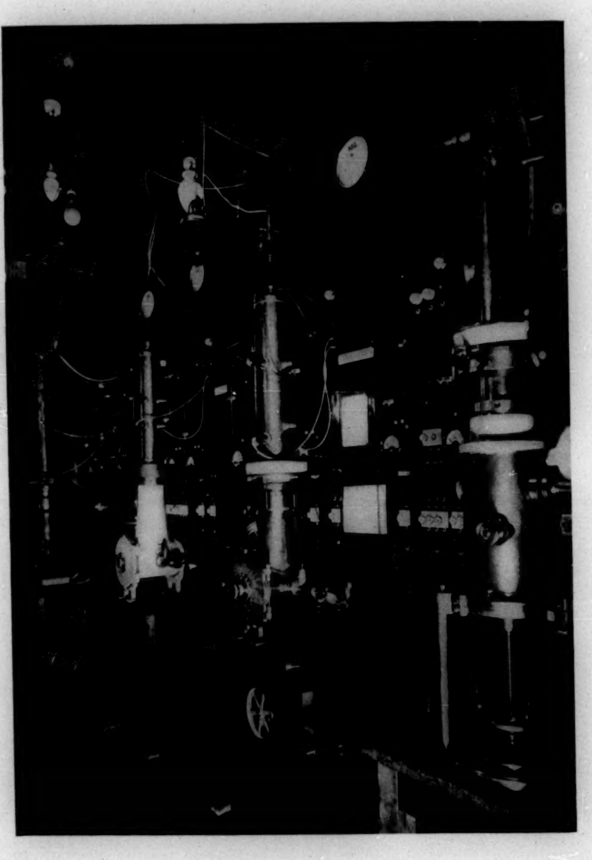
[4] H. Norinder: "Teknisk Tidskrift," 55; 8, Stockholm 1925.

[5] H. Norinder: "The Cathode Ray Oscillograph as Used in the Study of Lightning and other Surges on Transmission Lines." Presented at the Winter Convention of A. I. E. E. New York, N. Y. Febr. 13–17, 1928.

FIG. 2.



Cathode ray oscillograph equipments.

during the summer seasons it was possible during 1930–33 to record in the cathode ray oscillographs from one station 290 separate lightning discharges. All these were within a distance of 16 kilometers from the observation station. This was, as already mentioned, situated in the vicinity of Uppsala.

This paper will contain an account of the results drawn from the above mentioned 290 oscillograms of lightning discharges. It has obviously not been possible to analyze each individual lightning discharge in its details. Some of the oscillograms were too alike for such an individual treatment. Many of them were on the other hand too complicated to allow a detailed analysis. With regard to special details we have in the gathered observation results analyzed only the lightning discharges, that seemed to be most typical. In this connection it must be observed that all oscillograms analyzed in this paper have been taken from the antenna circuit system without any amplifier and with the antenna circuit directly connected to the oscillographic system.

The oscillographic records have, so far as it was possible, been supplemented by visual observations of the lightning paths. An observer has in all cases, when there was a chance, designed the discharge paths and localised them with regard to distance, azimuth and angular height. Lightning flashes with typical vertical or horizontal paths have been especially observed and noted.

BASIS OF METHOD.

In our experiments there was used a horizontal antenna wire of a length of 92 meters and a height above the ground of 19 meters. The diameter of the wire was 1.0 millimeter and the effective capacity of the system including connections to the oscillographic system was 500 $\mu\mu F$. We are, with regard to the placement and the horizontal level of the ground, able to consider this antenna wire to be mainly exposed in an equipotential surface. With the field force expressed in volt/meter to be E we have thus the potential at the height h above ground to be hE. With the field force lines directed down to earth we have the circuit of Fig. 3 where R_1 represents the damping circuit and R_2 the discharge resistance above which the voltage variation V connected to the oscillograph was recorded.

The relation between V and E is given by the equation:

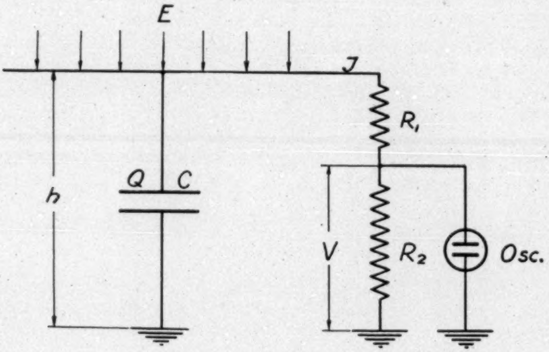
$$\frac{dE}{dt} = \frac{R_1 + R_2}{hR_2}\left\{\frac{dV}{dt} + \frac{1}{(R_1 + R_2)C}V\right\}. \tag{1}$$

We have in our case $R_1 \ll R_2$ (e.g. $R_1 = 250\ \Omega$, $R_2 = 20{,}000\ \Omega$), and R_1 can thus be omitted in comparison with R_2. This considered and with $R_2 = R$ we have

$$\frac{dE}{dt} = \frac{1}{h}\left\{\frac{dV}{dt} + \frac{1}{RC}V\right\}. \tag{2}$$

The sign of the right hand member depends on how the sign of the oscillographic voltage is determined. Using the sign of E of Fig. 3 with the lines of force against earth and supposing an increasing of the field force with time the result will be a positive sign of the right hand member of (2). Which of the two terms dV/dt or $(1/RC)V$ is preponderating depends on the sloping ratio of the recorded curve and on the value of RC. With a small value of R we have approximately:

FIG. 3.



Antenna circuit.

$$\frac{dE}{dt} = \frac{1}{hRC}V \qquad \text{or} \qquad E = \frac{1}{hRC}\int V dt. \tag{3}$$

In this case the second term is the preponderant one. With a high value of R (2) will be transformed into

$$\frac{dE}{dt} = \frac{1}{h}\frac{dV}{dt} \qquad \text{or} \qquad E = hV. \qquad (4)$$

In this case the first term is the more important.

The second term preponderates in our observations. We can on the other hand, as can be drawn from the following calculation, not neglect the first term. An ordinary partial lightning impulse will have from our observations a mean duration of 60 μsec.[6] The sloping ratio for such a mean curve is 16 volts/μsec. and thus approximately $dV/dt = 16$ volts/μsec. Using our values $R = 20{,}000\ \Omega$, $C = 500\ \mu\mu F$, thus $RC = 10$ μsec., we have $V/RC = 80$ volts/μsec. The second term is thus the more important. But we can on the other hand not neglect the correction caused by the first term in our calculations.

PROGRAMME OF OBSERVATIONS.

The observations to be discussed in this paper have been taken during 13 thunderstorms passing in the proximity of Uppsala during the years 1931, 1932 and 1933. All lightning discharges recorded were within a distance not exceeding 16 kilometers from the locality of observation. The records have, as already mentioned, been completed by visual observations of the lightning paths. It should in this connection have been of considerable value to obtain at least some photographic records of the lightning paths but the daylight during the summer nights in Sweden prevented us from obtaining such photographs.

THE TIME AXIS USED.

Our earlier observations of lightning discharges showed very complicated variation forms. The most usual seemed to be a set of partial discharges following one after another with short time differences and probably along the same lightning path. These partial discharges showed within themselves very rapid and characteristic variations. From this point of view it was not easy to choose a suitable time basis, which at the same time allowed a record of detailed variations and a general survey of the discharge procedure. We selected after some trials a sinusoidal time axis as the most convenient in this respect. The sinusoidal time axis necessitated when the curves had to be calculated a replot of the curves in a linear time scale, a procedure which was possible either by a mechanical arrangement or by direct reading of consecutive points from the record of the oscillographic curves.

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[6] In the following a microsecond is marked with μsec.

The rapid field changes were in our researches observed with a sinusoidal time axis of 25 or 50 kilocycles, and thus with time of 20 or 10 μsec. for one time sweep. The method allowed very short phenomena to be taken up by the oscillograph. In order to obtain a general survey of a lightning discharge composed by consecutive partial discharges we used on the other hand a time axis of quite another order of magnitude and with a time axis of 10^4 μsec. for one sweep.

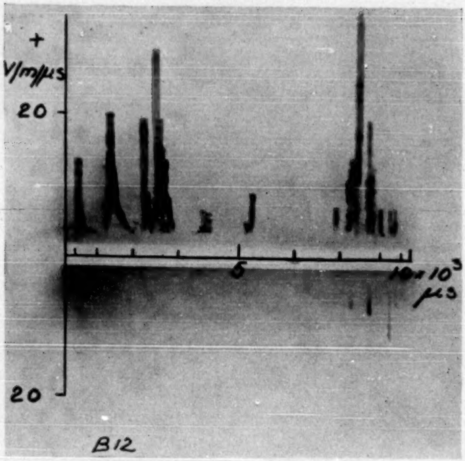
A. THE GENERAL DISCHARGE CHARACTER OF A FLASH OF LIGHTNING.

The general discharge character of a flash of lightning was observed at 46 different lightning strokes. As a time axis of 10^4 μsec. was used at these observations partial discharges not surpassing a total duration of 200 μsec. became recorded in the oscillograms as vertical lines against the time axis. A partial discharge with a total duration of more than 200 μsec. occurred sometimes. Such partial discharges of longer duration can be observed as extended curves along the time axis in some of the following records.

Two oscillograms with a record of 10^4 μsec. duration are reproduced in Figs. 4–5. For comparison we reproduced in Fig. 6 a similar record from distant discharges taken with a linear time axis and with an improved method.

In order to obtain a general survey of the mechanism of lightnings as built up by consecutive discharges we have in Figs. 7–11 reproduced in linear time scale some of the most typical records, which were taken with the above mentioned slow moving method. Each number in these figures represents what has been visually observed as a separate flash of lightning. We have in this recorded lightnings, when it was possible, observed the corresponding distances from the observation point to the lightning path. Such distance values in

FIG. 4.



Records of partial lightning discharges.

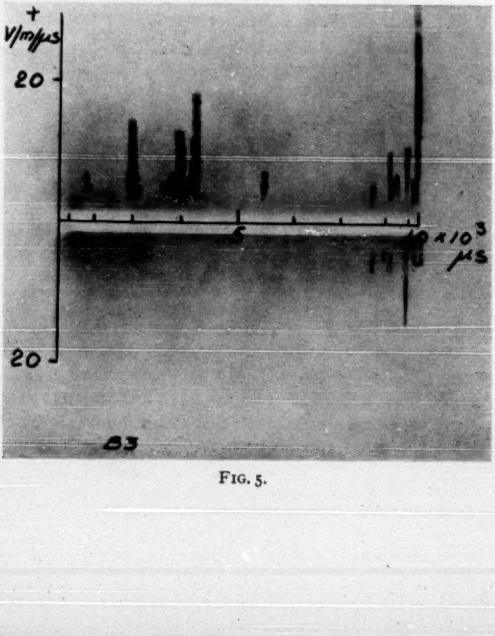
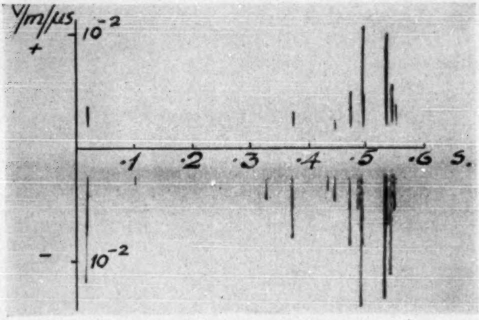


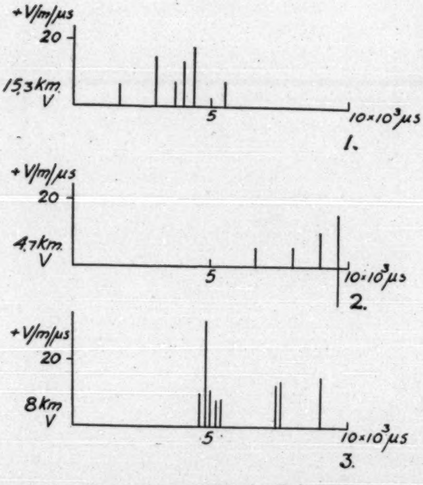
FIG. 5.

FIG. 6.



Distant discharges with improved methods.

FIG. 7.



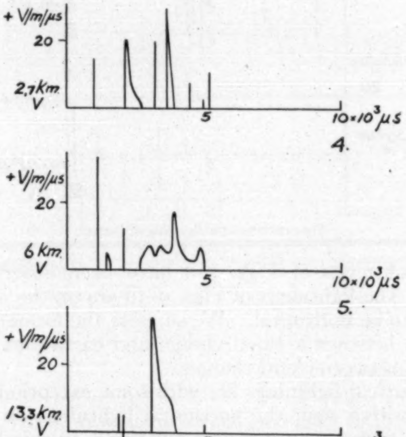
Consecutive partial lightning discharges.

kilometers when observed are reproduced in the curves of Figs. 7–11.

It will be noted as one of our most important results that a lightning discharge, observed as a distinct flash of lightning consists of several partial impulses one following after the other with different time intervals between them.

Obviously not all of these partial discharges are constituted by a heavy current flow between the discharge regions. Some of the partial discharges are to be considered as very thin glow streamers by which the heavy current flow is initiated.

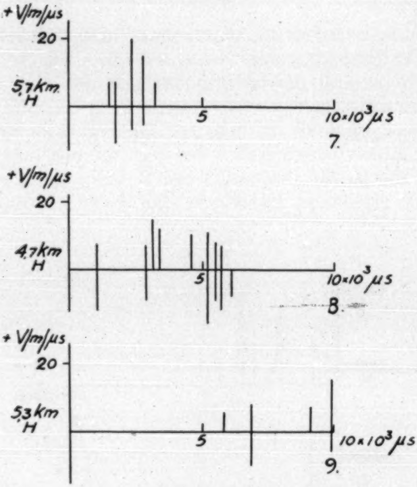
FIG. 8.



Consecutive partial lightning discharges.

This is from a physical point of view quite plausible. The first discharges which penetrate the air reduce the resistance in the main path and its side branches and provoke a much easier way for the following pulses along the same and ionised path.

FIG. 9.



Consecutive partial lightning discharges.

The lightnings of Figs. 7–8 have been observed to be vertical. The lightnings of Figs. 9–10 are on the other hand observed to be horizontal. We suppose the former to belong to strokes between a cloud charge and earth and the latter to strokes between cloud charges.

The vertical lightnings are with some exceptions unipolar and of positive sign, the horizontal lightnings on the other hand have a pronounced double polarity. In this latter case we must calculate with a bipolar cloud discharge, which in general will cause a bipolar reverse in surrounding fields.

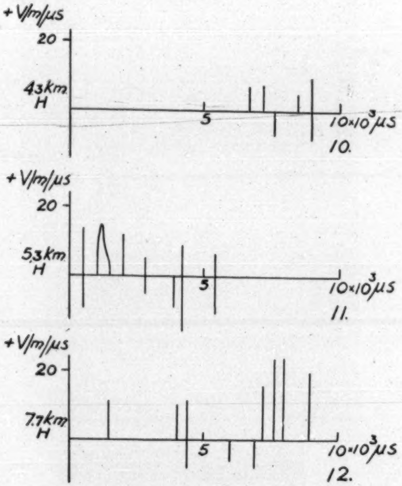
It is of interest to note the polarity of the 46 lightnings observed with the slow moving method. Of them 25 have a double polarity and 21 a single polarity. Of the latter 16 are positive and 5 negative.

The time between consecutive partial discharges is not shorter than 200 µsec. and is not longer than 3000 µsec. The total procedure with partial discharges is of the order of 10^4 μsec.

We have noted without exception that all partial discharges with a pronounced long duration are positive. The impulses with a short duration have on the other hand been either positive or both positive and negative.

The current direction in the aerial system has led us to consider the positive discharges as being caused by a destruction of a negative cloud charge or an increasing of a positive cloud charge. It has been evident from our oscillographic investigations that positive discharges have a pronounced longer duration than negative discharges. Such typical positive discharges of long duration are visible in Figs. 8, 10 and 11.

FIG. 10.

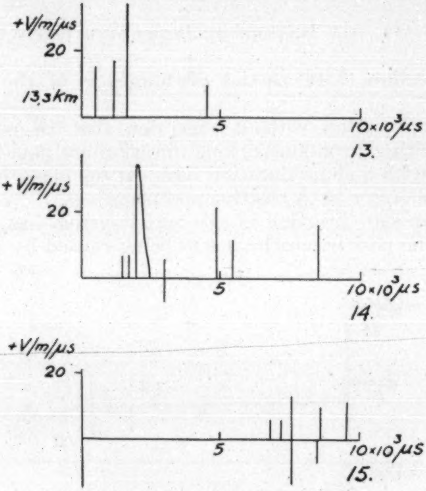


Consecutive partial lightning discharges.

B. ANALYSIS OF DETAILS IN THE MECHANISM OF LIGHTNING DISCHARGES.

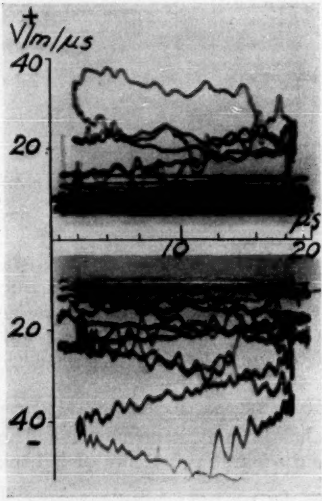
We used as has already been mentioned for the analysis of details in the discharge procedure of lightning a time axis

FIG. 11.



Consecutive partial lightning discharges.

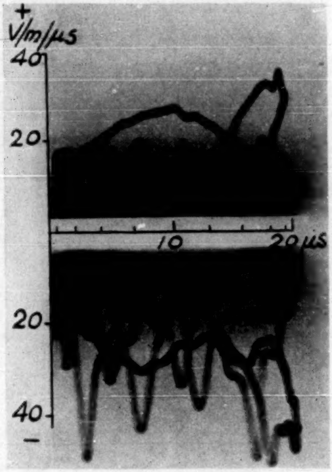
FIG. 12.



Oscillogram of a lightning discharge with superimposed rapid variations.

in the oscillograms of 10 or 20 microseconds. There were 140 oscillograms of this kind available for discussion and some typical of them are reproduced in Figs. 12–14. The extreme complexity of the oscillograms obtained caused in some cases difficulties and an analysis of the oscillograms had to be performed with precaution. This was especially the case when the partial discharges were extended over more than 5 periods of the time axis and when they were followed by consecutive partial discharges with lower amplitude.

FIG. 13.

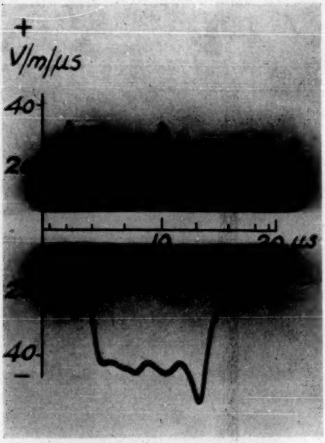


Oscillogram of a lightning discharge.

The ideal in such a case would have been to use simultaneously two oscillographs with different time axis, one slow moving and one rapid. In investigations still proceeding this method is used.

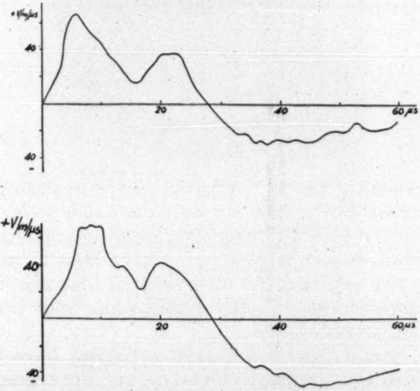
Some typical partial discharge variations have been replotted from the original oscillograms and are reproduced in Figs. 15–17. It may be observed in this connection that the

FIG. 14.



Oscillogram of a lightning discharge.

FIG. 15.

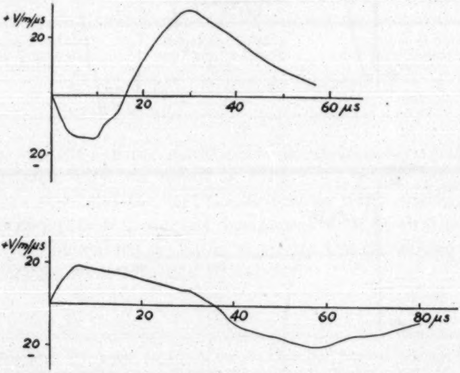


Partial discharges of two separate lightnings replotted in linear time scale.

zero target (marked with *n* : *r* 4 in Fig. 1) in the author's cathode ray oscillograph construction prevents a record near the zero line. The curves of Figs. 15–17 have been interpolated for this lacking part in as much as the regular form of the curves made such an interpolation allowable.

It may be noted that the curves of the two partial discharges in Fig. 15 belong to different lightnings separated a few minutes from each other. These discharges were observed to be emitted from the same thunderstorm cloud. Such similar discharge forms have their physical explanation in an electrostatic stability which sometimes can be significant during many minutes in the discharge development of a thunderstorm cloud. During this time of stability consecutive lightnings will discharge with quite similar variation forms.

FIG. 16.

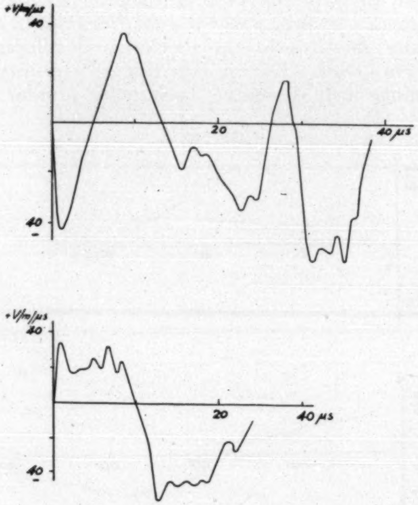


Typical variation form of partial lightning discharges with double polarity.

Partial discharges with variation forms very often observed in our oscillographic material are exemplified in Fig. 18.

Examples of partial discharges of a short variation type are reproduced in Fig. 17. The curves originate from two different lightnings in the same thunderstorm cloud. They show both superimposed variations of a very short duration of only a few microseconds. We have during the whole observation period received 22 oscillograms, where such superimposed unipolar variations of short duration are visible during some intervals of the discharge procedure. Their duration have been between 0.2 to 8 μsec. with 1–2 μsec. as the most frequent mean value. We have in some partial lightning discharges observed 50–75 such superimposed variations. Our present observations are not numerous and extended enough to permit an explanation of the physical origin of these interesting superimposed short pulses.

FIG. 17.



Partial lightning discharges with superimposed rapid variations.

The variation form with a duration longer than 10 μsec. belongs to a discharge form of which the lightnings in general are built up. It was thus of special interest to classify and compare such variation forms both with regard to duration and polarity.

The results are tabulated in Table 1.

TABLE 1.

Intervals of Duration µsec.	>300 µsec.	300 200.	200 100.	100 50.	50 25.	25 15.	15 10.
Positive polarity number......	9	11	30	9	20	21	11
Negative polarity number.....	3	2	6	9	3	2	5

It is obvious from Table 1 how partial discharges with positive polarity are preponderant. We calculate for instance in the interval 100–10 µsec. a number of 61 impulses with positive polarity and only 18 with negative. A comparison of the duration of partial impulses of positive polarity against those of the negative resulted in Table 2.

TABLE 2.

Duration of Positive Polarity Greater than Negative.	Duration of Positive and Negative Polarity Alike.	Duration of Positive Polarity Smaller than Negative.
92	18	30

This majority of the duration of positive polarity is quite in accordance with our result in Figs. 8–11, where long durations were observed for vertical lightnings with positive sign.

A consideration of partial discharges with double polarity resulted in the values of Table 3, where the durations of the two polarities were summed together.

TABLE 3.

Total Duration.	>600.	600–500.	500–400.	400–300.	300–200.	200–100.	100–0.
Number..........	(6)	1	3	9	15	31	75

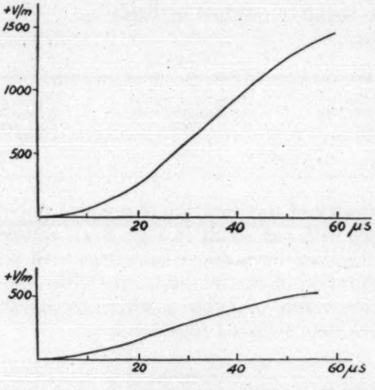
The most frequent total duration times of partial impulses seemed to be values from 200 µsec. down to 50 µsec.

As a special case may be considered such discharges where only one polarity is observed in the same discharge. We have of such oscillograms 47 of which 32 are of positive polarity and 15 of negative.

C. CALCULATION OF THE FIELD VARIATIONS FROM LIGHTNING DISCHARGES.

The physical conditions governing a lightning discharge in a thunderstorm cloud are, as we have already mentioned, very complicated. The variations in the field force caused by a lightning must thus result in values with pronounced differences with regard to intensity and general aspect. There is in this connection one feature of the lightning discharges that cannot be neglected. The lightnings represent in their development a shifting scale of a discharge procedure from the first thin glow streamers to the heavy strokes. In the latter cases the lightning paths are built up successively in the form of partial discharges.

FIG. 18.

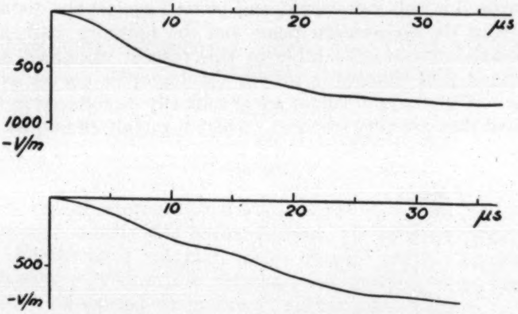


Calculated field variations caused by typical lightning discharges.

Many of the oscillographic curves which represent the dV/dt variations were regular and allowed by integration from relation (2), page 722 a calculation of the corresponding field force in volt/meter.

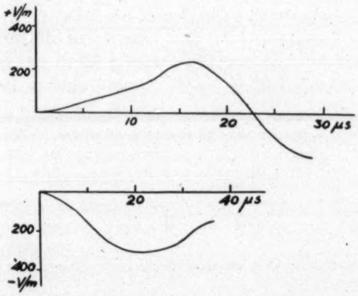
These integrated curves are representative of the variation form after which the partial discharges are developed in the lightnings. A group of such curves have been reproduced in Figs. 18–20 and represent partial discharges within 2–7 kilometers distance from the locality of observation. The curves

FIG. 19.



Calculated field variations caused by typical lightning discharges.

FIG. 20.



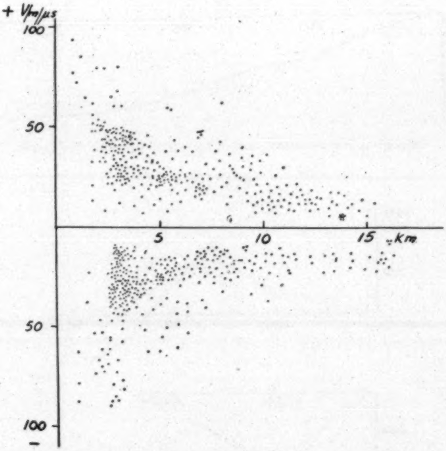
Calculated field variations caused by typical lightning discharges.

of the figures reproduce the calculated variation in volts/meter from an arbitrary initial value of E_0. It is obvious that the used method has not allowed a determination of the absolute value of E_0. Such a determination was on the other hand not of especial interest in this connection as much as the E_0 value is influenced by the electrostatic field from accumulated charges between the discharge and the observation region.

The curves of Figs. 18–20 represent such variation forms, which we consider as typical in the gathered material.

The observed maximal field change in partial discharges expressed in volt/meter/μsec. and plotted against the distance between the observation point and the lightning path is of especial interest. We have in this respect examined such maximal field changes in all our oscillographic curves available. The obtained values are graphically reproduced in Fig. 21 and they are very scattered, which is mainly caused by the difference in intensity of the lightning discharges. The values permit on the other hand an approximate determination of the limits of variation in the maximal field changes produced by lightnings. It is a matter of fact that we are not able to expect a more regular variation of the field changes as caused by such shifting discharge phenomena as lightning.

FIG. 21.



Maximal field changes from lightnings in relation to the distance of the discharge channel.

THE MAGNETOSTRICTIVE OSCILLATION OF CHLADNI PLATES.*

BY

R. C. COLWELL, Ph.D., and E. A. BRYANT, M.S.,

Department of Physics, West Virginia University.

A rod of magnetic material placed in a helix which is carrying a rapidly alternating current, will be set in vibration by the changing magnetic field. Under proper conditions such a rod may vibrate at very high frequencies. If a Chladni plate is supported upon the vibrating magnetic rod it too will be forced into oscillation by mechanical impact and its nodal lines may be made visible by scattering sand upon it according to the method of Chladni. In order to obtain vibrations which were on the border line between audio and radio frequencies we made use of a vacuum tube circuit shown in Fig. 1. The power tube was capable of developing 75 watts; but it was always kept much below its maximum power by the negative charge on the grid circuit coming from the direct current battery shown in the figure. This was done because we wished to force the rod *E* into different vibrations on both sides of its natural period and not to vibrate it with maximum energy at that period. After trying many different materials and shapes, it was found that the best results were obtained from a pure nickel rod ten inches in length and one-eighth of an inch in diameter. All the figures shown were produced upon this rod. The coils setting the rod in vibration at audio frequency were at the same time giving out a radio wave which could be measured on a wavemeter. These readings were between 12,000 and 15,000 vibrations per second. The different frequencies were produced by changing the variable capacities in the grid and plate circuits. Some difficulty was encountered in producing a steady oscillation since the rod always tended to vibrate at its own natural

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* Contribution No. 95 of the Division of Industrial Sciences of West Virginia University.

FIG. 1.

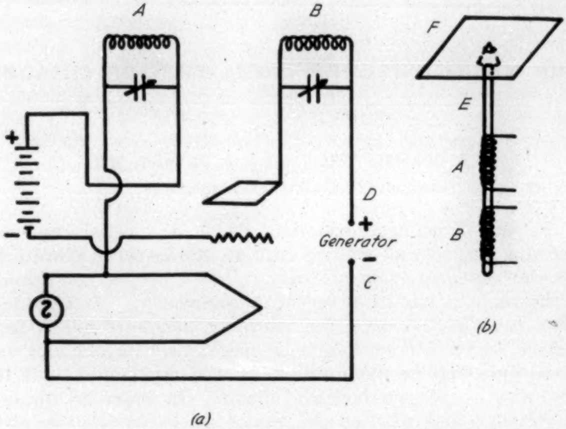


FIG. 1*a*.
A, *B*—the coils of the oscillating system. *D*, *C*—motor generator, 1500 to 2500 volts.

FIG. 1*b*.
A, *B*—in proper vertical position. *E*—the magnetostrictive rod. *F*—the Chladni plate.

freqencies. Then too the slightest change in the voltage of the direct current on the plate varies the note sufficiently to destroy the Chladni pattern.

Although the circuit had measured oscillations varying from twelve to fifteen kilocycles per second, the Chladni plates vibrated at the same frequency or at certain octaves of the rod below the actual frequency. The heavy plates vibrated below the frequency of the rod, while the thin plates occasionally vibrated in unison with the rod. This corresponds to the fact that a quartz crystal used as a stabilizer in radio sending stations can be made to send out vibrations which are multiples of the fundamental frequency.

The frequencies of two plates for certain patterns were therefore calculated from the equations

$$N = k\sqrt{m^4 + n^4 + 2(1 - \mu)m^2n^2},^{1} \qquad (1)$$

[1, 2] Ritz, *Ann. der Phys.*, 28, 1909, pp. 741 and 767.

where

$$k = \frac{\pi h}{2500}\sqrt{\frac{E}{3\rho(1 - \mu^2)}}. \tag{2}$$

The constants for the two brass plates were as follows:—25 cms. square; $h = 5/64$ cms.; $h = 5/128$ cms.; $E = 9.2 \times 10^{11}$ dynes/cms.^{2}; $\rho = 8.44$; $\mu = .25$. The calculations are necessarily only approximate since the formulas are not accurate for small values of m and n. However the value of k was checked by comparing the notes of the plates with a vibrating tuning fork. The calculated value of k was found to be 20 (approximately) while the comparison with the fork yielded values from 21 to 22.

The table below gives a very inaccurate ratio between the two vibrations but it verifies roughly the truth of the preceding statements.

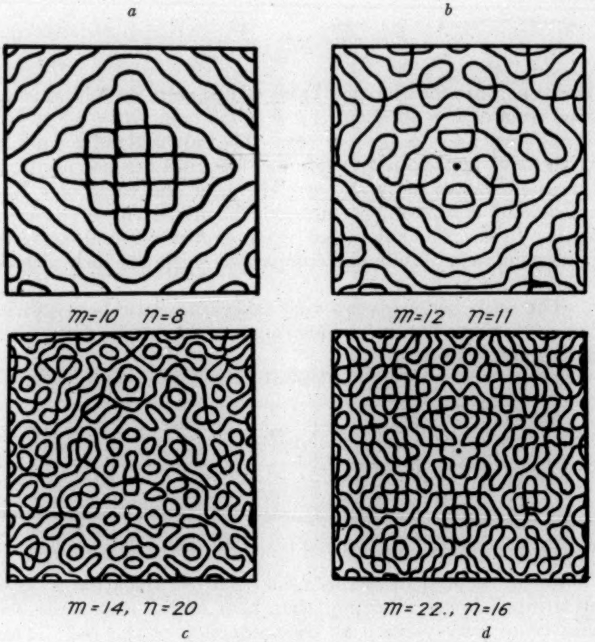
TABLE I.

Fig.	x axis.	y axis.	Calculated Frequency.	Radio Frequency.	Ratio of Frequencies Approximate.	Brass Plate Inches.
2 *a*	10	8	3,000	12,000	4	10 × 10 × 1/16
2 *b*	12	11	4,960	15,000	3	10 × 10 × 1/16
2 *c*	14	20	11,200	14,000	11/14	10 × 10 × 1/32
2 *d*	22	16	13,960	14,000	1	10 × 10 × 1/32

It can be seen from this table that the thick plate takes up a much lower vibration than that of the rod, while the thin plate may vibrate at the frequency of the rod. This indicates that any attempt to obtain more complicated figures will necessitate the use of thinner plates; but the one which are now being used are so thin that they tend to bend under their own weight, giving rise to strains in the brass and distorting the plane surface of the plates. It appears then that figures with more nodal lines than the ones shown here cannot be produced on this type of plate.

In Fig. 2 are shown some of the nodal lines formed by the action of the magnetostrictive rod. The m and n for each pattern were determined by counting the number of points along the x and y axes; this proceeding is rendered uncertain by the fact that some nodal lines are nearly tangential at the

FIG. 2.



a m=10 n=8

b m=12 n=11

c m=14, n=20

d m=22., n=16

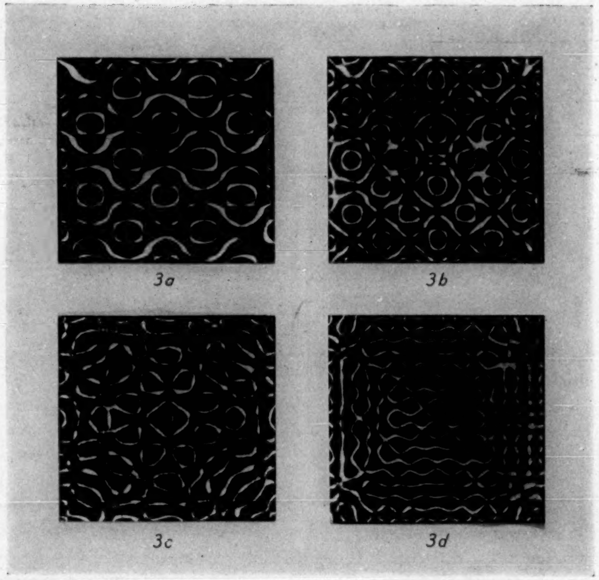
Chladni patterns on square plates with approximate values of *m* and *n*.

edges of the plate so that it is impossible to decide whether one or two nodal intersections should be counted at these tangential points.

The nodal patterns of Fig. 3 were formed upon a square brass plate 10 × 10 inches square and 1/16 of an inch thick. This heavy weight loaded down the magnetostrictive rod so that the resulting vibrations in the plate were not very high, hence the patterns are not particularly complicated.

A circular plate (Fig. 4) 10 inches in diameter and 1/32 of an inch thick showed the circles and diameters required

FIG. 3.



Photographic reproductions of sand patterns on square plates.

by Kirchhoff's equations, but it can be seen that there are other patterns not covered by his theory.

While working with the magnetostrictive oscillator in the radio sending coils, it occurred to us that these rods might be made to vibrate in the output of a power amplifier. Accordingly a coil was wound around a nickel rod as shown in Fig. 5 so that a vibration in the coil set the rod into oscillation. This new type of vibrator displaced the telephone in the circuit used in former experiments.[3] In Fig. 6 is shown the

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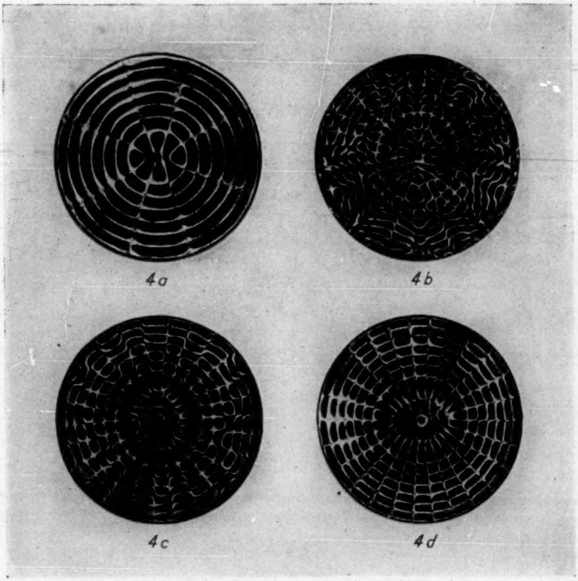
[3] *Phil. Mag.*, 12, Suppl. Aug. 1931, p. 320. JOURN. FRANKLIN INST., 214, No. 2, Aug. 1932, p. 199.

FIG. 4.

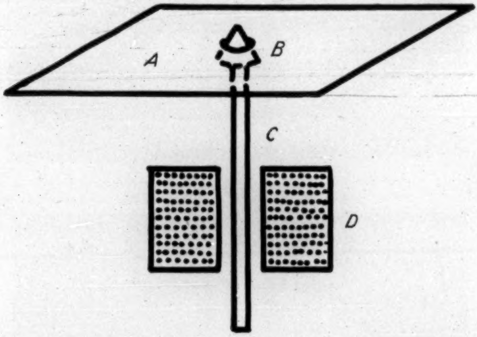


Photographic reproductions of patterns on circular plates.

complete apparatus for producing a high note with the power amplifier connected to the magnetostrictive oscillator; the Chladni plate is also shown mounted upon the end of the oscillating rod. In some cases the plate was clamped at its center and the pointed end of the cone applied to the bottom of the plate near its edge. This procedure gave rise to symmetrical figures as well as unsymmetrical ones.

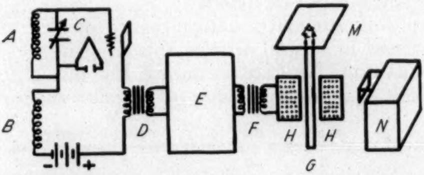
When the stand of the oscillator was resting upon a table with the Chladni plate balanced on the cone, it was possible to bring a wave meter close to the oscillating coil and so obtain the radio frequency of the current; but when the oscillator was held in the hands and pressed against the plate, it was impossible to get a steady reading on the wave meter. This was due to the fact that a very slight change in pressure on the plate would change the coupling between the plate and the oscillator. This change in coupling caused a variation in the frequency current which either disturbed the reading on the meter or destroyed the figure on the Chladni plate. These figures appear at such definite frequencies that a very slight change in the capacity attached to the vacuum tube will destroy any pattern that happens to be forming. When the frequency and the coupling are exactly correct, it

FIG. 5.



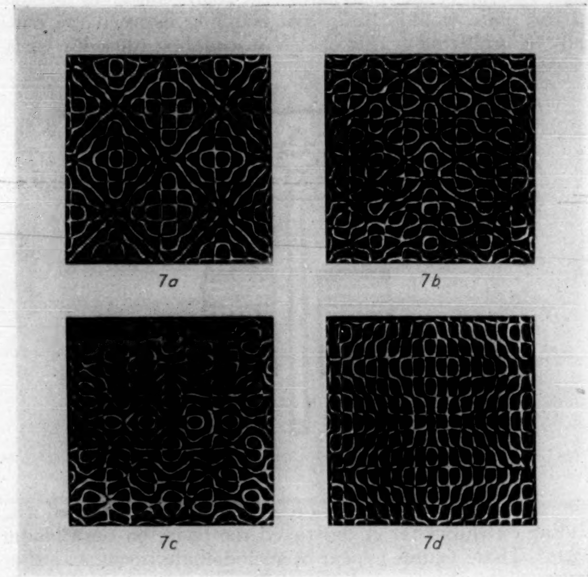
A—the Chladni plate; *B*—the cone on which the plate rests; *C*—the magnetostrictive rod; *D*—the coil which actuates the rod.

FIG. 6.



A, *B*—the primary and secondary of a variable audio-frequency transformer. *C*—the variable condenser which gives the close adjustment for the note on the Chladni plate. *D*, *F*—variable audio-frequency transformers. *E*—power amplifier—12 watts. *H*, *H*—the coil which actuates the magnetostrictive rod *G*. *M*—the Chladni plate; *N*—the wave meter.

FIG. 7.


7a
7b
7c
7d

Chladni patterns on square plates.

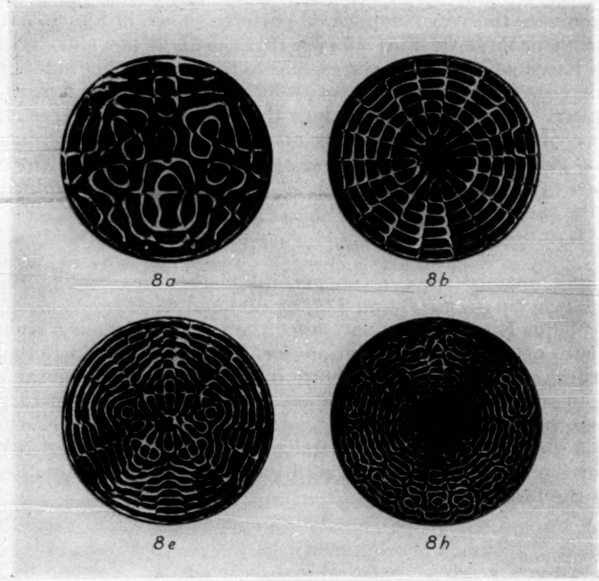
takes less than a minute to make the appropriate Chladni pattern on the plate; but many trials are required before the correct conditions can be found.

The approximate mathematical theory for these plates has been discussed in several articles appearing in the JOURNAL OF THE FRANKLIN INSTITUTE during the last three years. The simplest equation for square plates takes the form

$$w = A \cos \frac{m\pi x}{a} \cos \frac{n\pi y}{a} + B \cos \frac{n\pi x}{a} \cos \frac{m\pi y}{a} = 0. \qquad (2)$$

From this equation, it is possible to plot the nodal lines on the plate. The formula is more accurate for high vibrations than for low ones.

FIG. 8.



Chladni patterns on circular plates.

The patterns on the circular plates (Fig. 8) were made by clamping the plate at the middle and applying the oscillator near the rim. The number of nodal lines increases as the rate of vibration is made higher. Now Kirchhoff has given a solution for a circular plate with free edges.[4] It consists of the diameters

$$\cos(n\theta - \alpha) = 0 \tag{3}$$

together with the concentric circles whose equation is

$$J_n(kr) + \lambda J_n(ikr) = 0. \tag{4}$$

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[4] Rayleigh, "Sound," Vol. 1, p. 360.

These two equations will give all the circles and diameters actually found by experiment. They will not however account for the very complicated patterns shown in Fig. 8. To arrive at these we must suppose that the diameters and circles of Kirchhoff's solution correspond to the straight line solution for the square. Just as two solutions are combined in the square (equation 2) to produce the complicated patterns, so two of Kirchhoff's equations must be combined to produce the various figures for the circle. Let us write $f(\theta)$ for equation (3) and $\phi(r)$ for equation (4); then a second solution will take the form $F(\theta)$ and $\Phi(r)$.

$$w = Af(\theta)\phi(r) + BF(\theta)\Phi(r) = 0. \qquad (5)$$

Unfortunately there is no general method for finding the relation between $f(\theta)$ and $F(\theta)$ or $\phi(r)$ and $\Phi(r)$.

Thus Kirchhoff's equation for the circular plate is a complete mathemathical solution for all cases: but in actual practice, the plate may vibrate in two modes with the same note or with two notes which are so nearly identical that they may be regarded as the same note. In the latter case Kirchhoff's solution may be generalized by adding together two particular solutions. This addition gives rise to an equation of the form given in (5).

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

DEALERS' STOCKS OF CERTIFIED "ANALYTICAL" WEIGHTS.

Because the Bureau had been quoted as opposed to the carrying of stocks of certified weights by dealers, a request for a recommendation on the subject was received from one of the large laboratory supply houses.

In brief, the situation is as follows: (1) the carrying of such stocks is very desirable if weights do not change appreciably from the certified values. (2) Some sets of such weights do change so rapidly that certified values are of little use after the weights have been carried in stock even six months. (3) If weights change as rapidly as this, certification at the time of sale will give more accurately the values at that time, but these values may not be of great use to the purchaser because such weights will continue to change after he receives them. (4) In general, with screw-knob weights, the constancy of each individual weight depends on the care and skill with which it is made rather than on the material of which it is composed. (5) When tested at this Bureau, some, and possibly most, of the least constant weights are eliminated by the present determination of variations with atmospheric humidity. Some sets, however, change seriously but slowly, and are not conspicuously variable with humidity.

In view of this situation, the only definite, unqualified recommendation that can be made is that weights be tested for constancy, three months being about the least time that is sure to give valuable data. Any individual set that has been so tested and found constant may safely be carried in stock.

STRENGTH AND ELASTICITY OF GROUND COAT ENAMELS.

In Technical News Bulletin No. 202 (February, 1934), the method of determining the modulus of rupture of ground coat enamels was described, and some indications of the partially completed experiments were discussed. This study of strength and elasticity of some ground coat enamels has been completed, and the following conclusions, applicable to the range of compositions studied, were reached:

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* Communicated by the Director.

1. Substitutions of sodium and boric oxides, one for the other, and of feldspar and flint, one for the other, caused no important change in Young's modulus of elasticity, although a definite trend was observed.

2. The changes in modulus of rupture caused by such substitutions were relatively small and are outweighed by other considerations.

3. The changes in modulus of rupture with composition, though small, were systematic. Substituting boric oxide for sodium oxide increased the strength, and increasing the flint to about 30 per cent. with a corresponding reduction in feldspar below 30 per cent. caused an appreciable decrease in strength.

4. The scatter in the results on modulus of rupture varied systematically with the composition, and varied in some cases directly and in others inversely with the strength.

5. The computed extensibility of the enamels varied within a range of 0.14 to 0.19 per cent. in direct proportion to the modulus of rupture.

6. The frequency distribution of the strengths of different specimens of the respective enamels was approximately symmetrical.

7. The stress-strain curves for these enamels were linear up to the stress causing failure, and their slopes were not influenced by the rate of loading.

8. The time factor had a marked effect upon the apparent strengths, failure occurring at substantially lower stresses with increased duration of the stress periods.

TALC IN WHITEWARE.

An investigation is being conducted to determine some of the more important effects of MgO, introduced as a lime-free talc or as a lime-bearing amphibole (marketed as talc), in whiteware of the wall tile type. The maximum percentage of talc (or amphibole) in the bodies is 43, the minimum 2.5. Each series of specimens was heated to 1120°, 1180°, 1260°, and 1325° C. (or, approximately, to cones 1, 6, 10, and 14).

The values obtained to date show that: (*a*) an appreciable variation of MgO content did not significantly alter the water absorptivity of the heated bodies, this property being influenced much more, relatively, by the CaO and by the alkalies in the feldspar; (*b*) the total linear shrinkage was decreased, for specimens heated to 1260° C., from a maximum of 8 per cent. for a body containing no talc to a minimum of 0.7 per cent. for a body containing 43 per cent. talc. The shrinkage, also, was influenced significantly by the CaO in the amphibole and the alkalies in the feldspar; (*c*) moisture expansion was practically eliminated, but this must be accounted for in part by the low feldspar content; (*d*) the total linear thermal expansion to 700° C., considering specimens heated to 1260° and 1325° C. only, was decreased from a maximum of 0.93 per cent. for a body containing neither alkalies nor MgO to 0.35 per cent. for a body containing 15 per cent. amphibole. In general the thermal expansions increased as the percentage of talc or of amphibole was increased over 30 per cent. and, other factors being equal, expansions of bodies containing talc were higher than of the comparable bodies of the amphibole series.

THE SYSTEM: K_2O-PbO-SiO_2.

A preliminary survey of this system indicates that it contains three ternary compounds having the molecular ratios 1 : 2 : 2, 1 : 3 : 6, and 1 : 1 : 4, respectively. The first, crystallizing as hexagonal plates, is uniaxial negative, has indices 1.93 ± 0.01, 1.72 ± 0.01, and the optic axis perpendicular to the cleavage. The second, crystallizing as well defined fibers or lathes and resembling a short fibered asbestos when crushed, has indices ranging from 1.69 ± 0.01 to 1.79 ± 0.01, extinction is parallel, and the optic axis is parallel with the longitudinal axis. The third crystallizes as rectangular, platy granules of parallel extinction, and the indices range from 1.59 ± 0.005 to 1.65 ± 0.005. It is probably biaxial.

The linear thermal expansion to 300° C., and the softening temperature, of the three compositions, as glasses, are respectively: 0.46 per cent. and 395° C.; 0.28 per cent. and 461° C.; and, 0.24 per cent. and 517° C.

DETERMINATION OF SILVER IN VERY DILUTE SOLUTIONS.

Recent interest in the oligodynamic properties of silver, that is, its bactericidal powers, has brought about the demand for an accurate analytical method for determining silver in very dilute solutions. Concentration of silver of the order of 0.02 to 0.20 milligram per liter are concerned.

The research associates on engineering uses of silver at the Bureau have devoted some attention to this problem. Feigl's rhodanine test, which has been shown by Feigl and others to be accurate for quantitative estimation of silver in concentrations as low as 1 part in 5,000,000, has been selected as a promising method. The accuracy of this method in extremely dilute solutions was found to be very seriously affected by the adsorption of silver on the walls of glass vessels used in the analytical procedure. The amount of adsorption on glass may be considerably modified by the type of glass used or by certain treatments of the glass surface prior to use in the analytical procedure. This adsorption appears to be far less serious if vessels of fused quartz are used. With proper regard for these adsorption phenomena it appears, from preliminary experiments, that the rhodanine colorimetric method for silver will be applicable to concentrations of the order of those encountered in the bactericidal uses of this metal.

IMPROVED EQUIPMENT FOR STUDYING AGING OF RUBBER.

Improved equipment for studying the aging of rubber has recently been installed at the Bureau. The equipment is designed to maintain rubber test samples at a temperature of 160° F. in circulating fresh air for considerable periods of time. Formerly large ovens were used for the purpose, but these had the disadvantage that samples sometimes became contaminated by volatile products from adjacent samples of different composition, so the present apparatus was built with a number of small ovens, one for each sample. To facilitate temperature control these ovens are mounted in thermostatically-controlled water baths. Circulation of fresh air is secured by providing each with a small inlet and a chimney. The insulation and distribution of heating elements are such that it is possible to obtain sufficiently uniform temperatures without stirring either the water bath or the air in the ovens.

USE OF SWEET POTATO STARCH IN PAPER INDUSTRY.

According to the results of the Bureau's experiments, sweet potato culls offer some possibility as a source of starch for sizing paper and for paper adhesive. The culls constitute a huge waste in the southern states, and this Bureau and the Bureau of Chemistry and Soils are jointly endeavoring to find ways of making profitable use of them.

Cornstarch and cassava starch are used extensively in book papers to improve their printing quality. The Bureau made and tested wood-fiber book papers sized with these starches and with sweet potato starch and the latter compared very favorably with the others. The same kind of experiments are now being made with rag-fiber papers.

Dextrin-made from cassava starch, which is imported, is used as an adhesive for postage stamps, envelopes, labels, and other paper products, and for this purpose it is superior to the present cornstarch dextrins as it has better adhesive quality. Gum made from sweet potato dextrin, however, was apparently equal to cassava gum in all respects.

It is planned to extend these semi-commercial tests to trials on a commercial scale as soon as sufficient sweet potato starch is made available through production of it in a commercial plant now being built.

SIMPLIFICATION OF INDUSTRIAL TRUCK AND TRAILER TIRES APPROVED.

The simplified practice recommendation for industrial truck and trailer tires, cured-on type, having been accorded the required degree of written approval by the industry, became effective November 1, 1934. This simplified schedule of sizes will be included in the current revision of Simplified Practice Recommendation R103–33, which applies to industrial truck and trailer tires of the pressed-on type and which became effective June 1, 1934. The new schedule for the cured-on type of tire was proposed and developed by the standing committee for Simplified Practice Recommendation R103–33 and includes the stock sizes of the cured-on type of solid tires for use on industrial trucks and trailers.

SIMPLIFICATION OF CUPOLA REFRACTORIES.

Simplified Practice Recommendation R154–34 covering cupola refractories is now available in printed form. This recommendation, proposed and formulated by the industry, contains a simplified list of sizes for cupola blocks, tap-out blocks, and slag hole blocks.

There are five tables in the recommendation, as follows: Table I—9″ × 6″ × 4″ cupola blocks; Table II—9″ × 4½″ × 4″ cupola blocks; Table III—two hole tap-out blocks; Table IV—one hole tap-out blocks; and Table V—slag hole blocks.

The recommendation represents a substantial reduction in the variety heretofore listed for regular stock purposes, especially for tap-out, and slag hole blocks.

The printed edition of the recommendation also contains a summary of the development of the project, the membership of the industry's standing committee, and a list of the associations and firms that have accepted the program. The publication contains five illustrations. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents apiece.

COMMERCIAL STANDARD FOR INTERCHANGEABLE GROUND GLASS JOINTS, STOPCOCKS, AND STOPPERS.

The purpose of Commercial Standard CS21–34, which has just been issued in printed form, is to provide dimensional requirements for obtaining, within practical limits, interchangeability in ground glass joints, stopcocks, and stoppers for ordinary laboratory and industrial work.

This standard covers: (1) interchangeable ground glass joints from 3 mm. to 65 mm. for laboratory and industrial glassware; (2) interchangeable straight-bore, ground glass stopcocks from 1 mm. to 10 mm. bore; (3) interchangeable ground glass stoppers from 8 mm. to 35 mm. diameters for volumetric flasks, stoppered Erlenmeyer flasks, stoppered cylinders, separatory funnels, and iodine determination flasks; and (4) interchangeable ground glass stoppers from 12.5 mm. to 40.3 mm. diameters for reagent bottles.

The standard also covers material and construction requirements for standard master plug and ring gages with dimensional tolerances, the required fit of mating gages with reference to each other, and fit of the finished product in working gages. The universal taper for all interchangeable ground glass joints, stopcocks, and stoppers is 1 to 10, the specified length of the ground zone varying with the product. A complete set of master gages is maintained by the industry at the Bureau for reference.

The success of the commercial standard for interchangeable ground glass joints, CS21–30, led the standing committee to extend the principle of interchangeability to stopcocks and stoppers. While the details of the specification have been carefully formulated, they may be considered for a period of time as on trial and subject to revision to suit composite experience. The personnel of the standing committee is given in the printed pamphlet together with a list of acceptors and a brief history of the project.

Interchangeable ground glass joints, stopcocks, and stoppers are identified by the letters "ST" entwined as a symbol on each member, followed by the size number and trade mark of the manufacturer.

This publication is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents per copy.

LIST OF AERONAUTICAL PUBLICATIONS.

The Bureau's list of aeronautical publications, Letter Circular LC–325, has just been revised and will be mailed on request to anyone having a real use for it. The majority of the reports of the Bureau's work in aeronautics have been published, not in its own series of publications, but in the Technical Reports and Technical Notes of the National Advisory Committee for Aeronautics and in scientific and technical journals. The present list is, therefore, the only one which includes all of the Bureau's many contributions in this field and it should prove valuable for reference purposes. The publications are grouped under six heads: aerodynamics; aircraft materials and construction; aeronautic power plants; aircraft instruments; aids to air navigation; and miscellaneous.

Nature's Mirrors of Radio Waves.—(*Science Service.*) J. A. RATCLIFFE of the Cavendish Laboratory, Cambridge, England, reports that thunderstorms shatter the radio "mirrors" of electrical particles hundreds of miles above the earth and cause poor reception. These "mirrors" are layers of ionized gases. Radio waves bounce off the underneath side of these layers and are reflected back to earth.

The Cavendish investigator found one particular electrical layer to be 78 miles above the earth before a thunderstorm arrived. During the storm, the layer dropped to a height of 65 miles, then returned to the 78-mile level as the electrical disturbance abated. Fifteen minutes later it mounted to 93 miles.

Much the same type of investigation is being conducted by B. DECAUX and J. B. GALLE, of the Paris Academy of Sciences. The method used was to send the note of an organ pipe from Paris to Algiers on a radio wave of 24.15 meters, and to return it to Paris on a wave-length of 24.65 meters. By combining the original note with the one sent back and projecting them on a cathode ray oscillograph, it was easy to detect any variation in the time required for the radio signal to travel from Paris to Algiers and return. At night the oscillograph figures showed that the time required for the signal to make the round trip varied by one-thousandth of a second, the whole time required for the journey being about one-hundredth second. These fluctuations in transmission time indicate that the height of the reflecting layer is continually changing at night, but remains at a fairly constant level during the day.

C.

THE FRANKLIN INSTITUTE.

STATED MEETING, NOVEMBER 21, 1934.

The regular monthly meeting of The Franklin Institute was called to order at 8.15 o'clock by the President, Mr. Nathan Hayward, before a gathering which filled the lecture hall to the maximum capacity. The President announced that as it was the monthly meeting certain items of business would be presented by the Secretary, Dr. McClenahan.

The Secretary said that in order to save time and perhaps facilitate understanding by the members of the Institute present he would make a statement concerning certain proposed amendments to the by-laws of the Institute, which were regularly submitted with the approval of the Board of Managers.

The Secretary stated that the Board of Managers recognized the changed conditions under which the museum operated as far as its membership was concerned. It was felt that the old type members of the Institute should be continued with all of their privileges but that certain new types of membership, to be known as Museum Memberships, should be instituted for those who are interested solely in attendance upon the museum or the planetarium. He therefore offered the following suggested amendments which had been submitted two months ago by Mr. W. C. Wetherill and Mr. Henry B. Allen and had been approved by the Board of Managers:

Amend Article II, Section 8, by altering the number 22 to read 25. The section would then read as follows:

> Section 8. Student members shall be students, in any educational institution, over sixteen and under twenty-five years of age. They shall pay annual dues of three dollars if they do not receive the JOURNAL OF THE FRANKLIN INSTITUTE and six dollars if they do receive the JOURNAL. The term of Student members shall be limited by the age of twenty-five years, after which they shall be eligible for transfer to the other classes of membership upon the payment of the appropriate fee or dues.

He moved to amend Section 10 by calling Section 10, Section 9 and by omitting the clause "of whatever class" and by adding at the end of Section 9 the sentence—All members shall have the right of unlimited attendance upon the museum and the planetarium. Section 9 would then read:

> Section 9. Privileges: All members are entitled to participate in the meetings of the Institute, in the use of the library, to receive tickets for lectures, to attend section meetings and to receive monthly one copy of the JOURNAL OF THE FRANKLIN INSTITUTE except that Student members and Honorary and Corresponding members shall not have the right to vote nor to hold office and Student members paying the three dollars annual dues shall not receive the JOURNAL of the Institute. All members shall have the right of unlimited attendance upon the museum and planetarium.

The Secretary submitted a new Section to be known as Section 10 dealing with Museum Memberships in The Franklin Institute.

> Section 10. Museum Memberships:
>
> (*a*) Supporting Memberships—A Supporting Membership shall be held by any person who shall pay in any calendar year twenty dollars

dues. The privileges of such membership are the same as those expressed in (*b*) Family Memberships.

(*b*) Family Memberships—Such memberships extend unlimited admissions to the museum and the planetarium to all persons who are named as members of the household by the one paying the fee. A separate card of admission will be sent to each person so named. The fee is ten dollars per year.

(*c*) Individual Memberships—Such memberships extend unlimited admissions to the museum and the planetarium to the individual who pays a fee of five dollars per year.

(*d*) Student Memberships—Such memberships shall extend unlimited admissions to the museum and the planetarium to a student in any educational institution who is over twelve years of age and under twenty-five years of age who shall pay in any calendar year two dollars dues.

Such memberships extend unlimited admissions to the museum and the planetarium. They carry with them no other privileges of The Franklin Institute.

Upon motion properly offered and seconded, the meeting unanimously adopted these proposed amendments.

The President announced there was no further business and introduced the lecturer of the evening, Mr. Francis Hodgkinson, Consulting Mechanical Engineer, of the Westinghouse Electric and Manufacturing Company. Mr. Hodgkinson spoke brilliantly in a thorough and interesting review of the development of the Steam Turbine. The audience displayed manifest interest and perfect attention.

The meeting adjourned at ten-ten with an expression of appreciation of Mr. Hodgkinson's talk by the President of the Institute.

HOWARD MCCLENAHAN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, November 14, 1934.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, NOVEMBER 14, 1934.

MR. CHARLES D. GALLOWAY *in the Chair.*

The following reports were presented for final action:

No. 2954: High Power Microscopy.

This report recommended the award of the John Price Wetherill Medal to Francis F. Lucas of The Bell Telephone Laboratories.

No. 2984: Warren Self-Starting Synchronous (Telechron) Motors.

This report recommended the award of the John Price Wetherill Medal to Henry Ellis Warren, President of the Warren Telechron Company, "In consideration of his invention of the Telechron motor—a small, limited-power, self-starting, synchronous motor having strong starting torque and synchronous torque characteristics."

The following report was presented for first reading:

No. 2987: Visagraph for the Blind.

GEO. A. HOADLEY,
Secretary to Committee.

NOTES FROM THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE.

THE SIGNIFICANCE OF J. CLAY'S IONIZATION DEPTH DATA IN RELATION TO THE NATURE OF THE PRIMARY COSMIC RADIATION.*

BY

W. F. G. SWANN, Director.

The latitude and directional effects in cosmic radiation necessitate the existence of charged particles entering our atmosphere with energies greater than 10^{10} electron volts. These particles, if of electron type, would, in passage through the atmosphere, lose but a fraction of their energy, so that they would arrive at the earth's surface with energies comparable with 10^{10} volts.

The latitude and directional effects necessitate the assumption that about 14 per cent. of the rays observed at sea-level are of energy greater than 10^{10} volts. On the other hand, it has been frequently asserted that cloud chamber experiments show far fewer rays than this number with energies comparable with the amount in question.

In a former communication [1] the writer has pointed out that harmonization of the cloud chamber experiments and the latitude and directional effects in these matters necessitates the assumption that corpuscular rays of sufficiently high energy (energy comparable to 10^{10} volts) do not ionize in the sense of producing ions at the rate of about 50 in each centimeter of their paths at atmospheric pressure. It is inferred, however, that they do produce from time to time showers of secondary rays of lower energy. These showers perpetuate the directions of the non-ionizing primaries, and hand on these directional characteristics in Geiger counter experiments. They would hand them on even in cloud chamber experiments, where, however, the secondary rays would reveal themselves only with the actual energies they possessed, i.e., with energies smaller than those of the primaries. The writer has further

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* Reprinted from the *Physical Review*, **46**, 432–434, September 1, 1934.

[1] "On the Nature of the Primary Cosmic Radiation," W. F. G. Swann. *Phys. Rev.*, **43**, No. 11, 945–946, June 1, 1933.

given theoretical reasons to substantiate the reasonableness of an absence of ordinary ionization in the case of very high energy primaries.[2] He has also pointed out [3] that the existence of such a state of affairs would result in a diminution of ionization in a vessel with increase of depth of the vessel below the surface of the medium (say water) until, a depth was reached at which the primary rays had lost enough energy to bring them into the region of energy in which they could ionize. Below this depth, the observed ionization in the vessel should show an increase followed by a decrease to zero in a range comparable with that representative of the total range of ionization of the primary particles in the medium.

In a recent communication,[4] J. Clay has found, at great depths, an increase of ionization followed by a sharp decrease to zero, the whole phenomenon being in harmony with the predictions cited above. The object of the present note is to call attention to this fact and to trace its significance in somewhat greater detail. Figure 1 represents a reproduction of Clay's curve. The ordinates represent relative values of the ionization at the depths given by the abscissæ. It will be observed that there is a hump at 250 meters followed by a relatively sharp fall to zero at about 270 meters.

Statement of Hypothesis and Development of Consequences.—For simplicity we shall consider the case of a corpuscular radiation of definite energy of such amount that the corpuscles can travel a distance L in the medium before their energy becomes reduced to the point at which ordinary ionization commences. After the energy has fallen to the region characterized by ionization, we shall suppose that the particle completes its range in a further distance l, in which distance it ionizes in the ordinary manner. For convenience we shall consider the atmosphere as compressed to a layer of the density of the medium under consideration (water), and shall picture it as lying on top of that medium, and forming part of it. We shall denote by h the distance below the surface and by θ the angle from the vertical. We shall suppose that the number of primary rays falling within the solid angle $\sin \theta \, d\theta \, d\varphi$ is

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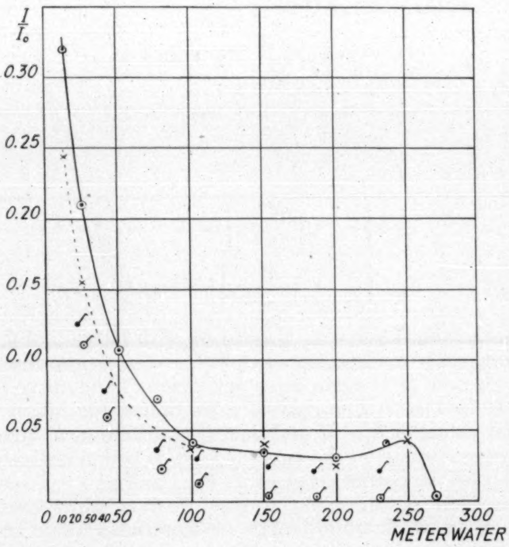
[2] "Representation of Radiation Reaction in Wave Mechanics," W. F. G. Swann. *Phys. Rev.*, **44**, No. 11, 943–944, December 1, 1933; JOUR. FRANK. INST., **217**, No. 1, 59–72, January, 1934. Also, W. F. G. Swann and A. Bramley, *Phys. Rev.*, **41**, 393, 1932.

[3] "Cosmic Rays," W. F. G. Swann. *Military Engineer*, Vol. XXVI, No. 146, 116–120, March–April, 1934. See in particular p. 120.

[4] "Results of the Dutch Cosmic-Ray Expedition 1933," J. Clay. *Physical* **1**, No. 5.

$$J = J_0 \cos^2 \theta \sin \theta \, d\theta \, d\varphi,$$

FIG. 1.



$\cos^2 \theta$ being the usually accepted empirical approximation to the result represented more exactly by the Gold formula, and φ being measured, of course, in the plane perpendicular to the vertical.

Consider an ionization chamber of volume V filled with gas at one atmosphere pressure. Then if q is the ionization per centimeter of path of the primary rays in the region of energy where they ionize, and if Q is the number of ions produced per second in the vessel by the primary rays, Q will be zero if $h > L + l$. Between the values of h given by $L + l$, and L, the value of Q will be

$$Q_1 = 2\pi VqJ_0 \int_0^{\theta_1} \cos^2 \theta \sin \theta \, d\theta,$$

where

$$\cos \theta_1 = h/(L + l);$$

for $h < L$, the value of Q is

$$Q_2 = 2\pi VqJ_0 \int_{\theta_2}^{\theta_1} \cos^2 \theta \sin \theta \, d\theta,$$

where

$$\cos \theta_1 = h/(L + l), \cos \theta_2 = h/L.$$

Thus

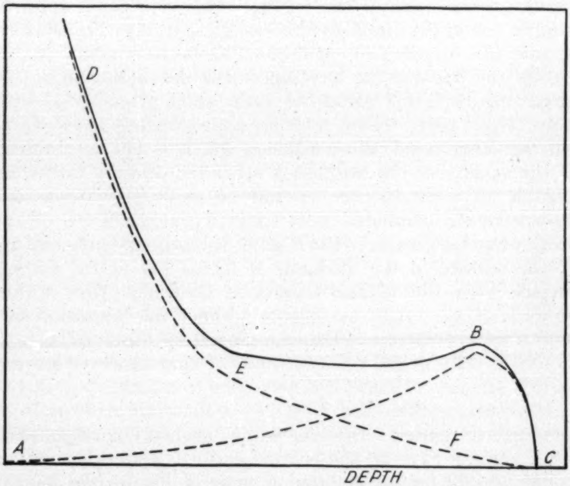
$$Q = 0 \text{ for } h > L + l, \tag{1}$$

$$Q = Q_1 = \frac{2\pi}{3} VqJ_0 \left[1 - \frac{h^3}{(L + l)^3} \right] \text{for } L < h < L + l, \tag{2}$$

$$Q = Q_2 = \frac{2\pi}{3} VqJ_0 \left[\frac{h^3}{L^3} - \frac{h^3}{(L + l)^3} \right] \text{for } h < L. \tag{3}$$

We notice that for $h < L$, Q *increases* with increase of h, and proportionally to the cube. For $L < h < L + l$, Q decreases with increase of h, again in cubic fashion. The curve for Q plotted against h thus rises to a maximum (or rather to a highest value) at $h = L$, and then falls to zero at $h = L + l$. The general shape of the curve is such as is qualitatively indicated by the dotted curve of A, B, C of Fig. 2. To obtain the complete ionization in the vessel we must superpose upon this a curve which, according to our hypothesis would be produced by the showers generated by the primaries. If the rate of production of showers decreases with decrease of energy of the rays attaining a sensibly zero value by the time the energy has reached the value at which ionization begins, we may expect to obtain a curve such as that qualitatively represented by the dotted curve D, E, F of Fig. 2. The combination of these two curves to the full curve thus gives the result similar to that shown by Clay's graph. On the basis of our hypothesis we should associate the point at 250 meters depth in Clay's curve with the point *B* of Fig. 2, and the point where Clay's curve cuts the horizontal axis at 270 meters should be associated with the point *C* of Fig. 2. The total range of ionization would thus correspond to a path of 20 meters in water. Now according to the theoretical curves quoted by P. M. S. Blackett and G. P. S. Occhialini,[5] as

FIG. 2.



obtained from the theoretical work of Bethe,[6] the energy loss, in ionization, per centimeter of path in water for rays of the order of 10^9 volts energy and of the electron type is about 2.5×10^6 volts per centimeter of path.[7] This gives 5×10^9 volts energy loss in 20 meters of water. Anderson's experimental data on absorption leads to an energy loss of 8×10^9 volts in 20 meters of water. It is a significant fact that the calculations of A. Bramley and the writer, based on the writer's theory already cited, suggests 10^{10} as the energy at which ionization should cease. The figures are not, of course, intended to give more than orders of magnitude; but, viewed in this light, it is of considerable interest to note that the magnitudes 5×10^9 to 8×10^9 volts found from Clay's curve on the basis of the present ideas represents approximately an upper limit to the energies of rays observed in appreciable numbers in cloud chamber measurements.

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[5] "Some Photographs of the Tracks of Penetrating Radiation," P. M. S. Blackett and G. P. S. Occhialini. *Proc. Roy. Soc.*, **A139**, 699–726 (1933).

[6] *Z. Physik*, **76**, p. 293 (1932).

[7] Bethe's theory would of course become invalid for energies higher than those where ionization ceases; but it would represent an approximation of the truth for lower energies.

On the basis of the foregoing ideas the ionization at 250 meters depth is representative of the value given by (2) with h put equal to L. This value is, approximately, $2\pi VqJ_0l/L$. On the other hand, the ionization which would be obtained at the surface of the medium if all of the primary rays were capable of ionizing there would be $2\pi VqJ_0/3$. Since our interpretation combined with Clay's curve gives l/L of the order of 20/280, we see that if all of the primary rays ionized at the surface of the medium, or let us say at the earth's surface with the normal ionization efficiency, they would produce (1/3) (1/14), i.e., about 5 times the ionization observed at 250 meters. But the ionization observed at 250 meters is only about one-twentieth of that observed at the earth's surface. Hence, it is necessary to assume that, at the earth's surface there are 20/5, i.e., 4 times as many rays as there are primaries. In other words, each ray is responsible for 4 shower rays at the earth's surface, and this number would be still further reduced if some of the surface ionization were caused by other ionization agencies, such as photons or their secondaries. The foregoing considerations render it possible that the showers concerned involve only one or two secondaries. In conclusion it may be added that we would hesitate to extend the ideas here involved in too great detail to the higher regions of the atmosphere. However, as appears from the foregoing, the main relevant facts are discussable in terms of a comparison of the ionization at the earth's surface with that at great depths.

THE ANNIHILATION OF THE PROTON.*

BY

ARTHUR BRAMLEY, Ph.D.

The experiments of Anderson, Millikan, Neddermeyer and Pickering,[1] and Gilbert[2] on the production of showers indicates that the immediate cause of the spray of negative and positive electrons observed in cloud photographs of the showers are gamma rays. The high energy gamma rays on striking a nuclear field lose their energy by generating a number of high energy pairs, negative and positive electrons. The origin of these hard gamma rays is obscure. Experiments indicate that these high energy quanta are probably not produced by electrons impinging on the nucleus. There then remains the possibility that their formation arises from the annihilation of matter, in a somewhat similar way to that suggested by Jeans[3] in his paper in the origin of cosmic rays. We shall give in this note an approximate expression for the probability $P(\eta)$ of the following process occurring. A high energy proton of K.E. ϵ strikes a nuclear Coulomb field of atomic number Z and is converted into a gamma ray and a positive electron of energy ηc.

In treating this problem we have followed the method suggested by Fermi for the treatment of the beta ray problem. We shall suppose that the wave function u_m of the proton is changed into the wave function Φ_n of a neutral particle and at the same time a positron and a photon of energy $h\nu$ appear in the field. According to Heisenberg we should consider the proton and neutral particle as two separate quantum states of the particle described through an inner quantum coördinate ρ:

$$\rho = +1 \quad \text{for the neutral particle,}$$
$$\rho = -1 \quad \text{for the proton.}$$

The passage from the proton to the neutral particle is determined through the operators $Q = \begin{vmatrix} 0 & 1 \\ 0 & 0 \end{vmatrix}$ and $Q^* = \begin{vmatrix} 0 & 0 \\ 1 & 0 \end{vmatrix}$, which operate on the coördinate ρ appearing in the Hamiltonian of the proton and neutral particle. The Hamiltonian function for the problem is composed of three terms, the energy H_1 of the proton and neutral particle, the energy H_2 of the quantum and positron and finally the coupling energy between the two sets of particles, H_3.

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* Reprinted from the *Physical Review*, **46**, 438–439, September 1, 1934.

[1] Anderson, Millikan, Neddermeyer and Pickering, *Phys. Rev.*, **45**, 352, 1934.

[2] Gilbert, *Proc. Roy. Soc.*, **144**, 559, 1934.

[3] Jeans, *Nature*, **116**, 861, 1925.

$$H_1 = \frac{1 + \rho}{2} N + \frac{1 - \rho}{2} P,$$

where N and P are the energy operators for the neutral particle and proton respectively. The wave functions for the positrons in the central field Ze are designated by ψ. The vector potential of the radiation field is analysed into a system of plane waves $a = \Sigma_i g^i A_i$. We shall assume that the coupling term is effective only at small distances and can be represented by the expression

$$H_3 = g\{Q\psi(x)\phi(x) + Q^*\psi(x)\phi(x)\} - e(\alpha A),$$

where the coördinates of the positron and neutral particle are taken at the position of the proton.

If the proton changes into a neutron and positron one of the neutral particles represents the neutron but if the mass of the proton is annihilated the neutral particle represents a neutrino. We have attempted in this way to give a mathematical description of a process which we recognize is but crudely represented by such a mechanism. In the case where the mass is annihilated, the failure of the law of the conservation of energy will be compensated by the energy imparted to the neutrino.

On the basis of these calculations, we have arrived at the following results. Similar conclusions were derived for the case of the decomposition of the proton into a positron and a neutron except that the order of magnitude will be different. The positrons are distributed in energy near their maximum energy according to a law similar to that which we are familiar in beta particle emission from radioactive nuclei in the same region. The total probability of this event $P = \int_0^{\eta_0} P(\eta)d\eta$, where $\eta_0 c$ is the maximum energy possible for the positron, varies as $(\eta_0)^5$ and is practically independent of the atomic number of the nucleus with which it collides.

The accuracy of these results is limited by a number of considerations: (1) the field of a nucleus cannot be represented by a Coulomb field at all distances; (2) the wave functions for the nucleus are unknown; (3) the interaction of the neutral particle, positron and proton has been given in a form similar to that used by Fermi in his treatment of the beta ray spectrum.—All these difficulties appear in the current theories of the beta ray spectrum of the radioactive elements[4] and finally (4) the representation of the annihilation of the proton as the change of the proton into a positron and neutrino may not be subject to simple quantum mechanical considerations on account of the large variation in mass involved. However, the general agreement of the theory with experiment in the case of the beta ray spectrum makes us hopeful that this theory of the annihilation of the proton may fairly well represent the facts.

According to these ideas, part of the primary cosmic rays are protons which on striking the outer atmosphere are converted in the majority of cases into a photon and a positron. Until the proton strikes a nucleus and is converted into a photon and positron, it loses its energy gradually by primary ionization along its path. As we have mentioned, the probability per nucleus of a collision with a nucleus in which the mass of the proton is annihilated is proportional to the fifth power of the maximum energy possible for the positron but is independent of the atomic number of the nucleus with which it makes the collision. The secondary gamma rays which are responsible for the showers should be absorbed per nucleus proportionally to the square of the atomic number of the nuclei of the medium in which the showers are produced but independent of their energy.[5] The observations of Kunze[6] on the rate of ionization of the high energy particles in cosmic rays supports the view that part of the particles are protons.

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[4] Fermi, *Zeits. f. Phys.*, **88**, 161, 1934.
Bramley, *Phys. Rev.*, **45**, 901, 1934.
Tamm, *Nature*, **133**, 981, 1934.
Iwanenko, *Nature*, **133**, 981, 1934.

[5] Oppenheimer and Plesset, *Phys. Rev.*, **44**, 53, 1933.

[6] Kunze, *Zeits. f. Phys.*, **83**, 1, 1933.
Williams, *Phys. Rev.*, **45**, 729, 1934.

RADIOACTIVITY INDUCED BY NEUTRON BOMBARDMENT.*

BY

ARTHUR BRAMLEY, Ph.D.

The experiments of Fermi[1] and Dunning (unpublished results on the induced β-particle emission from elements bombarded by neutrons) give added information concerning the nature of the nucleus. It leads to the idea that the ensemble of protons and neutrons forming the nucleus exert an appreciable force on the negative energy electrons within the nucleus and are thus capable of producing pairs—positron and electron. Whether this process occurs will depend on the value of the transition probability from the state in which the ψ-function represents the initial ensemble of protons and neutrons to that state in which the ψ-function represents the final ensemble of protons and neutrons together with a pair, positron and electron.

Thus if we have a reaction in which the neutron is captured by the element X_p^m and remains in that nucleus in an excited state, then through the possibility of the formation of a pair the following reaction can take place: the combination of the neutron with the positron to form a nuclear proton with the subsequent emission of the electron provided a transition is possible from the element $(X + n)_p^{m+1}$ to the element $(X + n)_{p+1}^{m+1}$. The possibility of this latter transition will depend on the value of the transition probability from the ψ-functon representing the state $(X + n)_p^{m+}$ to the ψ-function representing the final state $(X + n)_{p+1}^{m+1}$ together with a free electron. The idea that the selection rules governing the transition probability are a determining feature in nuclear reactions has been developed previously by Fermi,[2] and Bramley.[3]

Only further experiments can decide whether the nuclear pairs are produced by the nuclear protons or whether the neutrons have the power themselves to produce pairs.

These selection rules must be such that there cannot be more protons in the nucleus than neutrons, e.g., the series, $H^1D^2T^3He^4$. These rules indicate that T^3 should have a very small chance of forming a pair with the subsequent formation of He^3 and the emission of a free electron whereas T^3 should react readily with neutrons to form He^4 with the emission of a free electron. Whether the excess energy will appear as energy of the free electron or as hard γ-rays it is impossible to state.

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* Reprinted from the *Physical Review*, **45**, No. 12, 901–902, June 15, 1934.

[1] Fermi, *Nature*, **133**, 757 (1934).

[2] Fermi, *Zeits. f. Physik*, **88**, 161 (1934).

[3] Bramley, *Science*, **79**, 160 (1934).

We shall take as our final example, the case of the neutron bombardment of carbon. The reaction $C_6^{13} + n_0^1 \rightarrow C_6^{14} \rightarrow N_7^{14} + \epsilon^-$ is possible on this model but a radioactive reaction following the formation of $C_6^{13}C_6^{12} + n_0^1 \rightarrow C_6^{13}$ is improbable as C_6^{13} cannot make a transition to another existing element with the emission of an electron.

The process by which the nuclear electron, formed as one entity of the pair, escapes from the nucleus, is difficult to imagine. It may be that the nuclear barrier for electrons is much lower than we have supposed: the calculations of Kemble and Present[4] on the fine structure of $H\alpha$ indicate an effective nuclear radius of 5×10^{-12} cm.; the calculations of the writer[5] on the formation of x-rays by high energy electrons lead to a similar conclusion; the reaction $D^2 + D^2 \rightarrow T^3 + H^1$ requires an even larger effective collision radius to explain the rate of reaction.

COINCIDENCE COUNTER STUDIES OF THE CORPUSCULAR COMPONENT OF THE COSMIC RADIATION.*

BY

THOMAS H. JOHNSON, Assistant Director.

(ABSTRACT.)

The directional distribution of the cosmic radiation has been investigated in Peru, geomagnetic latitude λ0°, atmospheric depths $h = 6$, 6.8, and 10 meters of equivalent water; in Panama, λ20°, $h = 10$ meters; in Mexico, λ29°, $h = 6.8$, 7.2, and 10 meters; and in Pennsylvania and Colorado, λ50°,

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[4] Kemble and Present, *Phys. Rev.*, **44**, 1031 (1933).

[5] Bramley, *Nature*, **133**, 259 (1934).

* Published in full in *Physical Review*, May 1, 1934.

$h = 10$, and 7.2 meters. At each location the west intensity exceeded the east and the per cent. asymmetry was maximum near zenith-angles of 45°, falling off towards the horizon. At $h = 10$ meters the maximum asymmetry varied from 2 or 3 per cent. at $\lambda 50°$ to 8 or 10 per cent. at the equator and at $h = 6$ meters it attained 16 per cent. at the equator. It is shown that the observations cannot be accounted for as an effect of secondary rays, and from the Lemaitre-Vallarta theory expressions have been derived which relate both asymmetry and latitude-intensity-variations to a primary corpuscular component. The discovery of the asymmetry therefore establishes beyond doubt the existence of this component, already indicated by the latitude effect. Consistency between magnitudes of the two effects can be established only if the corpuscular component is exclusively positive. The magnitude and the absorption coefficient of this component associate it with the intense soft component of the absorption curve analyses of Millikan and Regener, with coefficient 0.55 per meter of water and containing some 98 per cent. of the radiation incident at the top of the atmosphere. Although the corpuscular radiation is widely distributed in energy, close analysis shows a band of greater-than-average intensity in the range of positron or proton energies from 1 to 1.8×10^{10} volts. Independent determinations of energy and absorption coefficient show disagreement in order of magnitude with the theory of energy loss by ionization, and the atmospheric range of the asymmetrical radiation is anomalously independent of primary energy. Both characteristics point to some other process for dissipation of energy. Studies have been made of the shower-producing radiation, and it is found that its absorption coefficient in the atmosphere agrees with that of the corpuscular component. The directions of shower-producing rays are likewise asymmetrically distributed showing them to be of positive corpuscular origin. Hence it is suggested that shower-production possibly accounts for the absorption anomalies. Studies of the shower-producing mechanism at high elevations have shown the existence of relatively soft intermediary rays which are also ionizing corpuscles. Studies of the zenith-angle distributions at high and low elevations have shown that the ratio of counts to electroscope ionization is less for the soft than for the harder components and a correction for this effect, probably arising from shower production, brings zenith-angle distributions into fair agreement with the absorption curve analysis of Bowen, Millikan and Neher. Difficulties in accounting for exclusively positive radiation by radioactive and secondary processes are enumerated and the existence of a radial cosmic electric field with the earth near its center is suggested. Acknowledgment is made of the support and coöperation of the Carnegie Institution, the Bartol Foundation, and of many individuals.

A POSSIBLE EXPLANATION OF THE FREQUENCY DISTRIBUTION OF SIZES OF HOFFMANN STÖSSE.*

BY

C. G. MONTGOMERY.

The cloud chamber photographs of Blackett and Occhialini, Anderson, and Locher [1] have brought to light the suggestion that Hoffmann Stösse may not originate in a single atom, but may arise from several atoms as the result of a primary cosmic ray acting through intermediaries. Each of these observers finds groups of ray tracks, apparently all formed simultaneously. These tracks are possibly produced by the particles which give rise to the bursts of ions observed in a pressure chamber. However, these tracks do not diverge from a common point, but seem, in many cases, to be formed in several groups, each group of tracks diverging from a separate point. The existence of these multiple centers has been attributed by Locher [1] to the action of neutrons which, coming from any one nuclear disintegration, serve to precipitate others. Experiments by W. F. G. Swann and the author are in progress at the present time for the purpose of testing this conclusion further and particularly to ascertain whether the size of a Stoss depends upon the amount of material involved.

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* Reprinted from the *Physical Review*, **45**, No. 1, 62–63, January 1, 1934.

[1] P. M. S. Blackett and G. Occhialini, *Proc. Roy. Soc. Lond.*, **A139**, 699 (1933); C. D. Anderson, *Phys. Rev.*, **43**, 368 (1933); G. L. Locher, *Phys. Rev.*, **44**, 779 (1933).

Data showing the frequency of occurrence of Stösse of different sizes have been published by Steinke and Schindler, and by Messerschmidt[2] and similar data have been taken at the Bartol Foundation with an apparatus which has been previously described.[3] These data all show the surprising fact that although a greater portion of the Stösse is grouped around a definite size, Stösse ten times this size occur fairly often. The object of the present note is to show how the coöperation of several atoms in the production of a Stoss would give rise to such a frequency distribution of Stoss sizes as is observed.

Let us suppose we have a block of material placed over an ionization chamber and suppose a group of rays is formed near the top of the block. These rays will contain among them entities capable of producing other groups and such secondary groups will be produced within the block. If the ranges of the ionizing rays are greater than the thickness of the block, then rays from both the primary and secondary groups will reach the ionization chamber and be recorded. Thus, on the average, if the primary group is formed near the top of the block of material, the number of ionizing rays which penetrate the ionization chamber will be larger than if the primary group is formed near the bottom of the block. Then the recorded Stösse will consist of a whole range of sizes similar to the observed range.

We can put the matter into a more quantitative form and obtain a rather good agreement with the observed distribution curves if we make a few simplifying assumptions. Let us suppose that the primary group will produce p ions in the chamber, and that p is independent of the position of the origin of the group. Also let us suppose that the rays of the primary group will produce a secondary group of size s ions, on the average, every a centimeters. Further let us suppose that each secondary group also produces groups of size s every a centimeters, and so forth. Then, if the primary group is formed at a distance r from the top of the block of material of thickness D, the size [4] of the resultant Stoss will be

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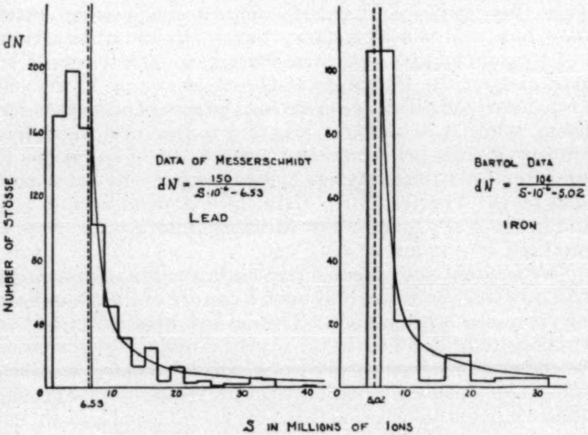
[2] E. Steinke and H. Schindler, *Zeits. f. Physik*, **75**, 115 (1932); W. Messerschmidt, *Zeits. f. Physik*, **78**, 688 (1932).

[3] W. F. G. Swann and C. G. Montgomery, *Phys. Rev.*, **44**, 52 (1933).

$$S = p + s(2^{(D-r/a)} - 1). \qquad (1)$$

Let us assume that the number of primary groups formed in the element of thickness dr is independent of r, then we can write $dN = kdr$ where k is a constant. From relation (1), we obtain

FIG. 1.



Observed and computed distributions of sizes of Stösse.

$$dS = -\,(\log 2/a)[S - (p - s)]dr$$

or

$$dr = -\,adS/\{\log 2[S - (p - s)]\}.$$

Then the form of the distribution curve will be given by

$$dN = -\,\frac{ak/\log 2}{S - (p - s)}\,; dS = -\,\frac{A}{S - b}dS.$$

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[4] The "2" in this expression results from the assumption that the number of groups doubles every "a" centimeters. As Dr. Swann has pointed out to the author, if the number of groups is derived by an integration process, the "2" becomes an "e."

This depends on only two parameters, and we may fit it to the observed distribution curves. The data of Steinke and Schindler are unsuitable for consideration in the present connection since they give a distribution curve for the difference in size of Stösse occurring simultaneously in two chambers placed side by side. However, we can compare Messerschmidt's results and those obtained at the Bartol Foundation with this empirical formula. The accompanying curves show how well this elementary theory fits the observations. For Messerschmidt's data, we obtain $A = 75$, $b = 6.53 \times 10^6$ ions, and for the Bartol data $A = 26$, $b = 5.02 \times 10^6$ ions. b represents the difference in size of a primary and a secondary group, while $A = ak/\log 2$, where k is the total number of primary groups per centimeter. Since the observations do not extend to sufficiently small sizes, we can only set a lower limit to it. For the Bartol data, $D = 2.5$ cm. iron, $k > 59$ and hence $a < 0.3$ cm. For Messerschmidt's data, $D = 10$ cm. lead, $k > 81$ and $a < 0.6$ cm.

We see that the observed curves, in their middle range at least, are well represented by such a picture of the Stoss-forming process as is given here. The deviations at either end are certainly to be ascribed to the overly simplified picture used. An elaboration of the theory would involve a closer specification of the probabilities of formation of the secondary groups, rather than the assumption that they are all equal. Although this would improve the agreement, it would only tend to complicate the calculations and would add nothing to the picture of the mechanism. However, the agreement is certainly good enough to regard the model used as a fair approximation to what actually happens. It is to be noticed that the essential idea in the process is that all groups, whether primary or secondary, are capable of producing other groups. The application of the picture of a primary group producing secondary groups all along its path (S in this case would vary linearly with r) is not capable of giving a distribution curve of the type observed.

The real importance of this picture of the formation of Stösse lies in the predictions that can be made from it. First, there should be a lower limit to the sizes of Stösse, and this limit is the size of the primary group of rays. If an upper limit of size exists, it probably depends upon the energy of the primary cosmic ray. Second, the distribution curves of Stoss sizes will depend upon the thickness of the material from which the Stösse come: thicker materials should give larger Stösse. There should also be observed "transition" effects if there is a primary or secondary Stoss size characteristic of the material. The lower limit of the size should, however, be dependent only upon the last material through which the Stoss particles pass.

In conclusion, the author wishes to express his thanks to Dr. W. F. G. Swann for his helpful encouragement and discussion of the ideas involved here.

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BOOK REVIEWS.

THEORETICAL PHYSICS, by W. Wilson, F.R.S., Vol. I, Mechanics and Heat, Newton-Carnot, 332 pages, illustrations, 14 × 22.5 cms. New York, E. P. Dutton & Co., Inc. Price $6.00.

This book is the result of the author's intention "to present an account of the theoretical side of physics which, without being too elaborate and voluminous, will nevertheless be sufficiently comprehensive to be useful to teachers and students." Such an ambitious project eventually will involve three volumes. This, the first, deals with mechanics and heat. In developing each subject, the author has quite naturally traced out its historical growth. The dynamical part is based on the foundations of Newton and the contents of this whole first volume are entirely "classical."

The hand of a teacher is easily recognized as having taken part in the preparation of Volume One in that allowances have been made for the more or less elementary mathematical equipment of its readers. As such, the methods of elementary vector and tensor calculus are introduced at the outset and consistently followed with intention of preparing the student for a more complete account of tensor calculus to be found in the later volumes.

The book begins with the purely mathematical considerations. The foundations of Euclidean tensor analysis are outlined and derivations given for the theorems of Gauss, Green and Stokes. Fourier's Expansion also receives attention. A chapter called Introduction to Dynamics is extended by one on the Dynamics of a Rigid Body Fixed at One Point and the subject summarized by a discussion of the Principles of Dynamics. Wave Propagation and Elasticity are topics having much in common. Hydrodynamics and Motion in Viscous Fluids contain much of practical significance. A study of the Kinetic Theory of Gases leads quite naturally to the question of Statistical Mechanics and the first Two Laws of Thermodynamics. A final chapter illustrates the Application of Thermodynamical Principles.

T. K. CLEVELAND.

THEORETICAL PHYSICS, by W. Wilson, F.R.S., Vol., II, Electromagnetism and Optics, Maxwell-Lorentz, 315 pages, illustrations, 14 × 23 cms. London, Methuen & Co., Ltd., New York, E. P. Dutton & Co., Inc. Price $5.75.

In this second volume, the author continues his exposition of theoretical physics in a manner closely identified with that of Volume One. It is well for all prospective readers to know that the subject matter has been chosen with one outstanding purpose in mind: "That of presenting physical theory as a coherent logical unity." In line with such intent it is shown how a mere change of notation in the electromagnetic field equation brings out the 4-dimensional appearance so characteristic of the theory of relativity. The relativity theory also is foreshadowed by a special treatment of electromagnetic momentum and mass.

The author carries his ideas of "coherent logical unity" still further and has labored to develop the electromagnetic formulæ in such a way that they are valid in any system of units the reader may wish to use. Although the numbering of the sections follows on from that of Volume One and many references also are made to the earlier volume, this present one on electricity and optics is remarkably self-contained.

Beginning with Electrostatics, the topic is extended to include a study of conditions in various Dielectric Media. Magnetostatics holds a brief introductory position to that of Electromagnetism which subject is expanded to include chapters on Inductive Circuits, Thermodynamical Aspects of Electric Currents (an interesting but little discussed topic) and the Electromagnetic Theory of Clerk-Maxwell. A discussion of Electronic theories concludes the electrical portion of the book. Geometrical Optics covers a discussion of reflection and refraction while interference and diffraction are classified as Physical Optics. Huygen's Principle is critically examined and special consideration given to Polarized Light and the Propagation of Light in Crystalline Media. The book ends with a thought-provoking chapter on General Questions Concerning the Propagation of Light.

T. K. CLEVELAND.

OUTLINES OF PAINT TECHNOLOGY, BASED ON HURST'S "PAINTERS' COLOURS, OILS, AND VARNISHES," by Noel Heaton, B.Sc., F.C.S., Hon.A.R.I.B.A., 400 pages, plates, 16 × 23 cms. London, Charles Griffin & Company, Ltd., Philadelphia, J. B. Lippincott Company, 1928. Price $8.00.

Most everyone can make claim to the status of amateur painter during a lifetime. This assertion implies painting in a decorative rather than artistic capacity. But before going on it is only fair to say that the author did not have amateur painters in mind when writing this book. However, if anybody who has experimented with the spreading of paint, varnish, lacquer or enamel, still possesses a desire to know how such are prepared, "Outlines of Paint Technology" is available for their edification.

Primarily this work is intended to serve as a general guide for students of paint technology and may be classified as a handbook of paint manufacture. Originally intended to be a revision of a much older work by another author, the many new developments in the paint industry have altered the former text to a degree that its identity is practically lost and a new book by a new author is the result. Well over one-half the space is taken with a discussion of pigments. These are classified according to major color groups. Preparation, composition, relative value for paints, and methods of testing are given with a fair amount of detail. Sources of additional information are indicated by references. Drying Oils and Driers are indispensable constituents of most paints and receive a critical evaluation by the author. Solvents and Plasticizers form a chapter of relatively new material and has been brought up to date. Resins, Gums, Waxes and

Bitumens are discussed in the light of their origin, preparation, distinctive characteristics and utilization. Special attention is given the manufacture of varnishes and lacquers with a view to anticipating any subsequent difficulties during and following application. Chapters on Paints and Enamels and, Cellulose Ester Products complete the roster. A number of useful Tables have been added. These classify the pigments according to their durability, composition, physical and chemical properties. Oils, solvents and resins also are tabulated according to their various characteristics. A Glossary of the pigments with their respective compositions is included and should prove a real help to those concerned with the manufacture of paint.

T. K. CLEVELAND.

CHEMICAL ENGINEERING CATALOG, 1934 (Nineteenth Annual) edition, collected, condensed and standardized catalog data of equipment, machinery, laboratory supplies, etc., with classified indexes of such equipment and materials, carefully cross-referenced and a technical and scientific books section . . . 779 pages, 21 × 29 cms. New York, Reinhold Publishing Corp., 1934.

The 1934 (Nineteenth Annual) edition of the Chemical Engineering Catalog is now on the shelf. The new Catalog is positive evidence of its Committee's successful efforts to improve it in the face of prevailing unfavorable business conditions in the chemical industry. The work of persuading manufacturers to include complete catalogs of their products brings greater results each year. More and more data on the properties and applications of listed chemicals are to be found and the Committee expects to enlarge upon this yearly.

A manufacturer or user of chemicals will find the Catalog practically indispensable. In the front (page 10) will be found a Trade Name Index telling the nature and maker of various types of equipment and manufactured products. Following the Classified Index of Equipment and Supplies are the individual catalogs of the manufacturers. Although the Section on Chemicals and Materials does not enjoy the magnitude of the one preceding, it nevertheless carries a complete list of the items industrially available today. It also is a great convenience to have the Laboratory and Reagent Chemicals grouped together. Every year the Technical and Scientific Books section is revised and brought up to date. We would like to see more publishers of technical and scientific books joining this section.

T. K. CLEVELAND.

FARADAY, by Thomas Martin, 143 pages, 12 × 19 cms. London, Gerald Duckworth, & Co., 1934. Price 2 shillings.

So often the biography of a great scientist is written by someone who has followed the same or a similar pathway. In such events, the scientific nature is apt to be stressed to the point of excluding other equally interesting phases of the character of such a great personage. We do not know whether the author of this book enjoys scientific pursuits, but if he does he has not permitted such propensities to bias an attempt to present a well-balanced appraisal of Michael Faraday.

This pocket-size volume is number forty of a series of Great Lives. It is written in a manner that renders it entertaining to scientist and layman alike.

No opportunity has been slighted in order to portray the human side of Faraday. His innumerable accomplishments are described without going into tiresome detail. In this volume will be found an account of the beginnings of what are today major developments in science. Many of these are attributable to Farady, others to his contemporaries. In truth, the curtain has been rolled back from a stage disclosing an epic of the first half of the nineteenth century.

T. K. CLEVELAND.

PUBLICATIONS RECEIVED.

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Mechanics for Beginners, by F. Barraclough and E. J. Holmyard, 214 pages, tables, illustrations, 13 × 18.5 cms. London, J. M. Dent and Sons, Ltd., New York, E. P. Dutton & Co., Inc. Price $1.00.

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CURRENT TOPICS.

The Brocken Ghost a Shadow.—The famous "Brocken Ghost" which had been "captured" for the first time last year by Dr. A. Brack, photographer of Zurich, Switzerland, was observed and photographed anew by a Mr. Lörtscher. This intrepid cameraman "laid" the spectre in its various phases from a mountain known as the Birre, 8218 feet above sea level, near Kandersteg in the Bernese Oberland. The apparition remained visible for thirty minutes and consisted of a perfectly outlined, but much elongated shadow of the photographer himself, surrounded by a rainbow-colored halo.

A low sun and fog below the summit of the mountain, also certain atmospheric conditions which prevail only at rare intervals are said to be responsible for this highly interesting phenomenon. The name "Brocken Ghost" is derived from the Brocken, the peak in the Hartz mountains, where for many years its appearance terrified the superstitious peasants of that region.

R.

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